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BULLETIN No. 127-74

STATUS OF SAN JOAQUIN VALLEY DRAINAGE PROBLEMS

DECEMBER 1974

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Secretary for Resources
The Resources Agency

RONALD REAGAN
Governor
State of California

JOHN R. TEERINK
Director
Department of Water Resources

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State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

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This bulletin was prepared as a responsibility of the
SAN JOAQUIN DISTRICT
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Direct assistance was provided by many past and present Department of Water Resources' employees who were assigned to the San Joaquin Valley Drainage Investigation for varying lengths of time.

Valuable input was provided by organizational units of the Department of Water Resources.

Significant input was received from officers and employees of many federal, state and local public agencies; plus many individuals, associations, organizations and corporations.

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CHAPTER I. INTRODUCTION, SUMMARY, AND CONCLUSIONS

The San Joaquin Valley faces a growing problem of salt management that threatens to disrupt the agricultural economy of the Valley, that endangers the quality of valley ground water supplies, that could degrade further the surface water supplies of the main stem of the San Joaquin River in both the Valley and the Delta, and that could decrease the productivity of more than a million acres of irrigated agricultural land.

Bulletin No. 127, "San Joaquin Valley Drainage Investigation--San Joaquin Master Drain", issued in preliminary form in January 1965, was prepared in response to directives contained in Senate Concurrent Resolution No. 27, adopted by the 1963 Session of the California Legislature.

While Bulletin No. 127 complied with the directives of SCR No. 27, some aspects of the salt management problems were left to future study. Bulletin No. 127 described the Valley's salt management problems at that time and contained specific recommendations that a master drain--from near Bakersfield to near Antioch Bridge--be constructed as a solution to the problems.

Since Bulletin No. 127 was prepared, a number of changes have occurred that are related to the San Joaquin Valley's drainage and salt management problems. Major changes outside of the Valley include:

--Establishment of stringent goals for water quality improvement and waste water management; reflected in the State's Porter-Cologne Water Quality Control Act and the federal PL 92-500, Federal Water Pollution Control Act Amendments of 1972.

--Implementation of activities to achieve water quality control and waste water management goals; reflected in the State's basin water quality control planning studies and the National Pollution Discharge Elimination System (NPDES).

--Substantial projected new demands for cooling water at inland thermal electric power plants.

--Increasing worldwide demand for agricultural products, changing relationship of the United States dollar to other currencies, and the United States balance of trade.

--Escalating costs of fuel and energy.

Physical changes and other activities related to drainage and salt management problems within the San Joaquin Valley include:

--Construction of greatly increased reservoir storage capacity on three major tributaries of the San Joaquin River.

--Construction of nearly half of the San Luis Drain, and scheduled construction of the remainder, by the U. S. Bureau of Reclamation.

--Construction of the start of an evaporation disposal system by the Tulare Lake Drainage District.

--Completion of the interagency nitrogen removal treatment studies at Firebaugh by the Department of Water Resources, the Bureau of Reclamation, and the Environmental Protection Agency.

--Present attempts to bring into being the San Joaquin Nuclear Power Plant.

These changes, and the changes they portend, establish a need for the Department of Water Resources to reactivate studies related to the drainage and salt management problems of the San Joaquin Valley.

This Bulletin

Bulletin No. 127-74 is a status report on the drainage and salt management problems of the San Joaquin Valley. It is an attempt to present the "big picture" with respect to a large-scale salt management system for the Valley. This Bulletin does not present a detailed technical discussion of drainage and salt management problems.

A description of the technical aspects of the problems is contained in a 20-page booklet entitled "Salt Management: California's Most Complex Water Quality Problem", published by the Division of Agricultural Sciences of the University of California in June 1974.

The first paragraph on page 11 of that booklet outlines the magnitude of the problem:

> "A few dozen or even a few hundred farm drainage systems do not add up to the kind of drainage network needed for permanent large-scale salt management. There are two other requirements: a place to put the wastes (a "salt sink") and, in many areas, a means of getting them there (a "master drain")."

Bulletin No. 127-74 describes the more than a million acres of on-farm drainage systems that will eventually be required in the Valley, the "salt sinks" that might be used both within and outside the Valley, and the "master drains" that might be used to move the salts from the farms to the salt sinks.

This bulletin is, in essence, a summary of the Department's San Joaquin Valley Drainage Investigation--which began in mid-1957 and concluded in mid-1973--and it also charts a course for future action by the Department.

Background

The salt management problem in the San Joaquin Valley is not a unique one; the problem has plagued irrigated agriculture in all arid and semiarid areas of the world since before the beginning of recorded history. Many flourishing early civilizations fell principally because of an inability to understand and cope with salt balance and drainage problems. The Tigris and Euphrates River valleys in ancient Mesopotamia became mostly desert because of accumulation of salts in the surface soil layers. Relics of abandoned irrigation systems, alkali areas, and salt accumulation extending from the Sahara Desert through ancient Persia show that a lack of proper drainage eventually resulted in the physical and economic ruin of vast agriculturally productive areas.

Salt management problems also have plagued modern-day farmers throughout the world. A decade ago, farmlands adjacent to major rivers of India and Pakistan were changing to barren salt flats at a rate of more than 30,000 acres a year. In the 1920s and early 1930s, many farm enterprises went bankrupt in the Imperial and Coachella Valleys due to salt balance and drainage problems. Prohibitions against lending money for farming in those areas were maintained by some financial institutions in the 1940s.

In the 1890s and early 1900s, sizable areas of the San Joaquin Valley were forced out of production by salt balance and drainage problems. The use of wells for irrigation, which lowered the ground water levels, combined with improved drainage and other efforts permitted reclamation of most of the land damaged at that time.

The modern-day salt balance problems of the San Joaquin Valley, however, are of far greater scope and severity, and will not yield to the simple methods of the turn of the century. The problems of the 1970s require massive and valley-wide solutions.

The Department's San Joaquin Valley Drainage Investigation was initiated in 1957 after hearings on drainage and water quality degradation problems in the Valley conducted by the Joint Legislative Committee on Water Problems, which followed department studies related to Bulletin No. 3, "The California Water Plan". Because of the size of the Valley--about eight million acres--it took several years to define the magnitude and scope of the salt management problem.

During the first three years of the Department's drainage investigation, interested persons and agencies worked to bring the Valley's drainage problems to the attention of legislators at both the state and federal levels. As a result of these activities, the Burns-Porter Act (which authorizes financing and construction of the State Water Project, and which was approved by the voters of California in 1960) authorizes the Department of Water Resources to construct "facilities for removal of drainage water from the San Joaquin Valley". Concurrently, the Congress of the United States was considering authorization of the San Luis unit of the Central Valley Project for construction by the U. S. Bureau of Reclamation. The San Luis Unit Authorizing Act (Public Law 86-488) was enacted by Congress in 1960 and required the Bureau of Reclamation to either participate with the State of California in "a master drainage outlet and disposal channel for the San Joaquin Valley" or to construct "the San Luis interceptor drain to the delta designed to meet the drainage requirements of the San Luis unit".

Authorization for the Bureau of Reclamation to participate in a state master drain was included in federal legislation at the urging of state officials in order to provide for a single efficient and economical drainage disposal facility.

The history of federal-state activities related to a valley master drain is one of reversals.

In 1961 the Department of Water Resources, in response to a question from the Bureau of Reclamation, stated that the Department had not completed planning and could not assure construction of a master drain in time to meet the Bureau's needs. The Department's letter of June 21, 1961, also stated that construction by the Bureau of Reclamation of the federal San Luis Interceptor Drain appeared to be the most direct and satisfactory manner of handling at least the first stage of works to serve the Valley.

In 1963 the Secretary of Interior announced that construction of the San Luis Interceptor Drain would start in early 1966 and that the drain would be ready for use in 1968. By late 1963, the Department's plans for a master drainage system were sufficiently developed that discussions of a joint federal-state facility were resumed.

On April 3, 1964, the Department advised the Bureau of Reclamation that it was prepared to offer assurance to the Secretary of Interior that a master drainage outlet and disposal channel for the Valley would be constructed by the State. This offer of assurance was favorably received by the Secretary of Interior.

On June 22, 1964, the Department sent to the Bureau a proposal for state construction of a master drain, which

was accompanied by a statement entitled "Basic Elements of Aasurance by the State of California to the Secretary of Interior Regarding Construction of the San Joaquin Master Drain in Place of the San Luis Interceptor Drain". The elements of assurance stated that a first stage of the Master Drain from near Kettleman City to the Delta would be completed not later than July 1, 1970.

From mid-1964 until late 1966, the Department and the Bureau worked on plans and designs and a federal-state contract for construction of the San Joaquin Master Drain. At the same time, the Department was attempting to develop assurances of repayment of the State's reimbursable costs for the drainage facilities as required under the contracting principles of the State Water Project.

On March 10, 1967, the Department wrote to the Bureau that it could not proceed with construction of the San Joaquin Master Drain because it was unable to obtain the assurances of repayment of the State's reimbursable costs. The same letter requested that the Bureau proceed with construction of the federal San Luis Interceptor Drain to serve the federal San Luis Unit service area.

The Department then asked San Joaquin Valley interests to form an advisory group to review the plans and planning of the Department, with particular emphasis on the development of an equitable plan for repayment of the State's reimbursable costs.

The San Joaquin Valley Drainage Advisory Group was subsequently created, reviewed the drainage plans, and after about 18 months produced a "Final Report" dated January 1969. The group's letter of transmittal, conclusions, and recommendations are Appendix A of this bulletin.

The Department's planning activities diminished greatly in 1969, and by 1970 were phased out except for the agricultural waste water nitrogen removal treatment studies (a joint effort of the Department of Water Resources, the U. S. Bureau of Reclamation, and the then Federal Water Pollution Control Administration --now part of the federal Environmental Protection Agency), desalting studies, and a tile drainage monitoring program. The nitrogen removal studies continued until mid-1973; the desalting studies and the tile drainage monitoring program continue.

When the San Joaquin Valley Drainage Investigation began, most of the on-farm tile drainage systems of the Valley were located in western Fresno County between the Cities of Mendota and Dos Palos, with a few installations at the north end of the Valley in San Joaquin and Contra Costa Counties. Agricultural waste waters from the Mendota-Dos Palos area were disposed of by dumping some into the water supply canals and conveying the remainder along with return flows to the Grasslands Water District--an area used for cattle grazing and duck hunting. The agricultural waste waters of San Joaquin and Contra Costa Counties were discharged into the channels of the southern and western Delta areas.

During the San Joaquin Drainage Investigation, a number of on-farm and areawide drainage systems were installed by individual farmers and special districts between Gustine and Tracy to lower saline ground waters that had risen within crop root zones. All of these systems are desigined for initial discharge into the San Joaquin River and later into a master drainage system. The density of on-farm inatallations increased in the Mendota-Dos Palos area

during the study, and scattered installations were made in the Kings and Kern County drainage problem areas.

The Tulare Lake Drainage District has completed a small evaporation disposal system. The Bureau of Reclamation has completed about 75 percent of the federal San Luis Drain from near Kettleman City to the Kesterson Reservoir east of Gustine. The Mendota-Dos Palos area agricultural waste waters continue to be delivered to the Grasslands Water District through an improved system for disposal on grazing lands and in duck ponds, and drainage systems from Gustine to the Delta are discharging into the San Joaquin River or the southern and western Delta channels.

There is a need to develop an integrated federal-state-local master drainage system that would incorporate or provide service to all of the existing waste water capture, conveyance, and disposal systems of the Valley. With a concentrated effort by all interested, affected, and concerned parties, such an integrated system can come into being.

Related Considerations

Federal and state laws related to water quality control and waste water management and the activities of governmental agencies responsible for implementation of those laws could have various effects on solutions to the drainage and salt management problems of the San Joaquin Valley. The precise effects are not known at this time. As background information, the relationship of the laws and the implementation activities to the Valley's drainage and salt management problems are discussed in this section.

State Water Resources Control Board (SWRCB) Basin Plans. Under authority of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and the State's Porter-Cologne Water Quality Control Act, the SWRCB has in progress 16 basin water quality control management plans for the State. These are scheduled to be approved by the State Board and submitted to the EPA by June 30, 1975. Upon submittal to the State Legislature, they become part of the California Water Plan. The San Joaquin River and Tulare Lake Basins are 2 of the 16 planning areas.

The plans are to furnish a framework to establish priorities for waste treatment facility construction grants, for the issuance of waste discharge permits, and to establish a flexible guide for protection and enhancement of the State's water quality. The plans will include beneficial uses to be protected, water quality objectives, means of achieving those objectives and monitoring programs to measure achievement.

In the San Joaquin River and Tulare Lake Basins, the major water quality problem is defined in preliminary reports as dissolved salts from agricultural return flows. It is expected that the basin plans will include water quality objectives for waters of the areas which will require that efforts be undertaken to alleviate problems resulting from agricultural return flows. Since elements of these plans are enforceable through the state and federal acts, they are expected to provide impetus toward solution of the areas' drainage and salt management problems.

The National Pollution Discharge Elimination System (NPDES). Under the federal PL 92-500 and current EPA regulations, a waste discharge permit was required by December 31, 1974, for

all point source waste discharges from irrigated farm operations of 3,000 acres or more. Point sources include agricultural return flows and discharges from tile drains. In California, the SWRCB has been given authority to administer the program. Applications currently are being solicited from agricultural interests. The Board is permitting agricultural entities to consolidate for application purposes.

The permits are expected to be issued for an initial two-year period and contain monitoring provisions only, since the best practicable control technology (as required in the federal law) for irrigated agriculture has not yet been defined.

It is expected that control measures considered necessary will be defined during and following the two-year initial permit period. These control measures within the framework of the basin water quality management plans may well include measures to prevent agricultural waste water --and particularly high salinity water from tile drains--from degrading freshwater supplies.

The NPDES permits, coupled with requirements of the basin water quality management plans, may result in substantial increased interest in means to dispose of high salinity agricultural waste water.

Possible Financial Assistance. Agricultural salt management systems consist of on-farm facilities, area-wide collection facilities, and a "master drain" to convey waste waters to point of ultimate disposal (a "salt sink"). The costs and benefits of these systems should be equitably distributed.

On-farm costs are generally a direct cost to the farm operator. However, increased land productivity benefits the community, state, and nation through increased food and fiber production, income and a larger tax base. Further, the basic drainage problem may result from up-slope irrigation, suggesting distribution of costs among those responsible as well as those faced with the problem. Current federal programs do offer some assistance in on-farm improvements.

Systems to collect drainage from multiple farm operations may be distributed among the users and the community as a whole. Master drainage systems to convey collected wastes to point of disposal and provide any necessary treatment may be beyond the ability of the local community to finance and provide repayment. The benefits of such a system are widely distributed.

State and federal assistance may be warranted. For municipal waste water treatment and disposal systems, the Federal Government grants up to 75 percent of eligible costs through PL 92-500. The State contributes an additional 12.5 percent through the State's Clean Water Bond Act. Agricultural master drain systems may be analogous to municipal waste treatment and disposal systems. While PL 92-500 does not specifically preclude grants for agricultural drainage, the legislative intent appears directed primarily toward municipal wastes. The requirement for repayment of costs by private industrial users may also be a barrier to government financing under the existing laws.

The National Water Commission on Water Quality was established by PL 92-500. The Commission has contracted for a study of the benefits and costs of achieving or not achieving the water quality goals established under PL 92-500 in a number of drainage basins of the nation--including the Central Valley-San Francisco Bay basin in California. In addition, the

Commission plans to contract for a national study of the impact of agricultural return flows on the water quality goals--including the financial aspects of agricultural waste water control.

A possible precedent for assistance in improving water quality is the Colorado River Salinity Control Act. That Act authorizes construction of various salinity control facilities in the Colorado River Basin to improve the quality of Colorado River water and provides that 75 percent of the cost will be nonreimbursable.

The Department's Current Program

The Department of Water Resources reactivated studies of the San Joaquin Valley's drainage and salt management problems, in mid-1974, with the primary objective of having a valleywide salt management system available when needed and before the Valley suffers a severe disruption of its economy.

In pursuing this objective the Department must work closely with the U. S. Bureau of Reclamation and the State Water Resources Control Board. The program also will involve many public agencies, groups, and individuals. Certain phases of the program will require significant contributions from the California Department of Fish and Game, the U. S. Fish and Wildlife Service, and the federal Environmental Protection Agency.

Planned, authorized, and partially constructed drainage disposal facilities that have developed within the last decade are the key factors in the development of the Department of Water Resources' current program of studies related to the drainage and salt management problems of the San Joaquin Valley. The primary considerations involved are:

--The Bureau of Reclamation has completed the first phase of Kesterson Reservoir and 87 miles, of 113 miles, (77 percent) of the San Luis Drain between Kesterson Reservoir and Kettleman City. About fiscal year 1977, the Bureau plans to start construction on the remaining 26 miles to Kettleman City. After fiscal year 1981, the Bureau plans to start construction from Kesterson Reservoir "to the Delta", in accordance with the San Luis Unit Authorizing Act. The San Luis Drain, as presently planned, physically could provide for the drainage disposal needs of the San Joaquin Valley from Kings County to the Delta until about 1990. It could be adequate for an additional period of years if storage of peak flows is provided, or the waste waters are reused.

--In the remainder of the Valley, primarily Kings and Kern Counties, the use of agricultural waste waters for power plant cooling at the proposed San Joaquin Nuclear Power Plant is being studied and promoted. In the interim, the Tulare Lake Drainage District has constructed relatively small evaporation disposal facilities, and has specific plans for expansion of that system when the need arises. The Kern County Water Agency has general plans for development of interim evaporation disposal facilities if the use for cooling water does not materialize in the reasonably near future. The existing and planned facilities and/or use could provide drainage disposal service in the remainder of the Valley until after 1990.

Considering the foregoing key factors, it is obvious that time will be available for monitoring the developing drainage and salt management problems of the San Joaquin Valley if existing and proposed facilities and uses are completed or become a reality.

Therefore, the first phase of the Department of Water Resources' current program will be:

--To encourage maximum reuse of agricultural waste waters within the San Joaquin Valley, with particular emphasis on use for power plant cooling in the Kings-Kern Counties area; and

--To encourage the completion of planned and authorized facilities, with particular emphasis on completion of the federal San Luis Drain; with provisions for interim drainage disposal service for lands between the San Luis Unit service area and its terminous.

The second phase of the Department's current program will be directed toward development of a fully approved jointly developed plan for a salt management system in the San Joaquin Valley--including an accepted, approved, and authorized plan for financing and repayment. Primary input for the phase two studies must come from local (San Joaquin Valley) interests.

Summary

Ever increasing salt management problems in the San Joaquin Valley are a growing threat to both the economy and the environment of the Valley. The salts threaten the productivity of the soils, endanger the Valley's ground water basin, and are degrading the surface water supplies in the main stem of the San Joaquin River.

The floor of the San Joaquin Valley encompasses about 8 million acres and slopes gently from the base of the Tehachapi Mountains on the south to the Delta on the north. A low divide which extends across the Valley floor between the San Joaquin and Kings Rivers separates the Valley into its two major hydrologic basins--the southerly Tulare Lake Basin and the northerly San Joaquin River Basin.

Except for major flood periods, the waters of the San Joaquin Valley are completely controlled by man. The primary water supplies of the Valley are obtained from east side streams, the Valley's ground water basin, and diversion from the south edge of the Delta.

Agriculture is the dominant segment of the economy of the San Joaquin Valley. The gross income from agricultural production was $3.6 billion in 1973 in the 8 valley floor counties--almost half of the statewide total of $7.5 billion. This multi-billion dollar economy of the San Joaquin Valley is threatened by the growing salt management problems.

The basic salt management problem of the Tulare Lake Basin differs from the problem of the San Joaquin River Basin. "Salt balance" is the basic problem of the Tulare Lake Basin and "salt level" is the basic problem of the San Joaquin River Basin.

The Tulare Lake Basin is a hydrologically closed basin; that is, there essentially is no outflow of water and consequently salts accumulate in the basin. Most of the salts come from sources within the basin. At about the 1990 level of development, an estimated 1.6 million tons of new salts will be added to the soils and water supplies of the Tulare Lake Basin each year. A master drain would not export the amount of salt that enters the Tulare Lake Basin--a master drain would provide a major step toward "salt balance" in the basin. If all of the subsurface agricultural waste waters of the Tulare Lake Basin were put into a salt management system, about 70 percent (1.1 million tons) of the annual new salts would come under the control of man.

At about the 1990 level of development in the San Joaquin River Basin, slightly more than 1.5 million tons of new salt will be added annually to the valley floor portion of the basin. At about the same point in time, there will be an estimated average annual outflow of 2.3 million acre-feet of water containing 2.4 million tons of salts. The San Joaquin River Basin, thus, can be said to have a "favorable salt balance"; but, without an alternative disposal channel, there will be an "unfavorable salt level" because all of the salts will be flowing from the basin in the San Joaquin River. The salt concentrations, or "salt level", would be high enough in drier years to damage orchard and truck crops. The higher salt levels in the San Joaquin River also would degrade agricultural water

supplies in the southern Delta. If the subsurface agricultural waste waters were placed in a salt management system (master drain), the salt level problems in the main stem of the San Joaquin River would be reduced but not eliminated.

A salt management system for the San Joaquin Valley almost exclusively would utilize subsurface agricultural waste waters (tile drainage) as the source of salt for management. Municipal and industrial waste waters generally are of a quality that is suitable for direct irrigation reuse. Oil field waste waters are becoming less of a problem as larger quantities are being injected back into the oil bearing underground formations.

About 1.7 million acres--nearly 25 percent of the irrigable land in the San Joaquin Valley--have a potential for development of saline drainage problems. About 1.2 million acres of the potential drainage problem area are irrigated. By the year 2000, an estimated one million acres will have tile drains or other drainage systems for the control of shallow saline ground waters that affect crop production.

Tile drainage system discharges today are estimated to be about 70,000 acre-feet per year. Within the next 30 to 50 years, the production of subsurface agricultural waste waters will rise to between 500,000 and 600,000 acre-feet per year. During the late 1970s the composite salt content of tile drainage waters is expected to range between 6,500 and 7,500 parts per million. Within 30 to 50 years, the composite salt content of the Valley's subsurface agricultural waste waters is expected to drop to between 2,000 to 3,000 parts per million.

Though not reusable for conventional irrigated agriculture there are a number of potential uses of the Valley's tile drainage waters that were considered during the course of the San Joaquin Valley Drainage Investigation. The agricultural waste waters could be utilized to maintain marsh lands in the valley. They are a potential source of cooling water for steam electric generating plants. The Valley's agricultural waste waters probably could be used to grow algae, fish or other aquatic life to provide an additional food source. Tile drainage waters also could be used for repressurization of some of the oil fields in the Tulare Lake Basin. Finally, irrigation of salt tolerant plants that could be used as livestock feed is another possible in-valley use of the agricultural waste waters.

If in-valley uses of the agricultural waste waters did not increase salt concentrations excessively, the agricultural waste waters could be used to help repel the intrusion of ocean salts into the western Delta-Suisun Bay area.

Various systems to bring the salts of the San Joaquin Valley under control of man were studied as part of the San Joaquin Valley Drainage Investigation. The systems discussed in this bulletin include desalting, evaporation on the valley floor, evaporation outside the valley floor, transportation systems over and through the Coast Range to the Pacific Ocean, and essentially gravity flow systems from near Bakersfield to near Antioch Bridge--including a discussion of five more westerly discharge points in the Suisun and San Pablo Bay areas. The total capital costs of the systems discussed in this bulletin range from $175 million to $990 million--with the two most costly systems providing capacity for the disposal of municipal and industrial waste waters from the Livermore and Santa Clara Valleys.

There are a number of existing or planned drainage disposal facilities that could and should become a part of a valley salt management system. About 75 percent of the Bureau of Reclamation's San Luis Drain is complete from Kettleman City to Kesterson Reservoir. The Tulare Lake Drainage District's initial evaporation ponds near Stratford are completed. Several smaller local systems exist between Gustine and the Delta. Drains between Mendota and Los Banos discharge agricultural waste waters and return flows into the Grasslands Water District for disposal. The Kern County Water Agency, in cooperation with the Department, is developing plans for making waste waters available for power plant cooling in northern Kern County. All of these facilities are compatible with most of the salt management systems described in this bulletin.

The impact of the discharge of agricultural waste waters on western Delta-Suisun Bay receiving waters was a matter of great concern after the 1965 proposal to construct the San Joaquin Master Drain. The then Federal Water Pollution Control Administration (FWPCA)--now part of the Federal Environmental Protection Agency--studied the problem during 1965 and 1966. A January 1967 report of the FWPCA concluded that salts and pesticides in tile drainage waters would not create a problem in the Delta receiving waters, but that nitrogen would stimulate the growth of algae and create problems. The report recommended that methods for removal of nitrate-nitrogen from the agricultural waste waters be studied.

The Bureau of Reclamation, the Environmental Protection Agency, and the Department of Water Resources conducted nitrogen removal treatment studies at an experiment station near Firebaugh. Three processes were studied--algal growth and harvesting, bacterial denitrification, and symbiotic (algae and bacteria). The EPA, based on its regrowth studies, concluded that "nitrogen removal from agricultural drainage is definitely effective in reducing biostimulation". The total capitalized costs of the various treatment configurations range from about $70 million to about $240 million. Land requirements for the treatment facilities range from less than 200 acres to more than 30,000 acres.

The problems which are delaying implementation of a salt management system in the San Joaquin Valley primarily are financial and social, or political. The financial problem is that the State must have assurance of repayment of reimbursable costs before commencing construction. On the other hand, the farmers in the drainage problem areas, based on estimates of the San Joaquin Valley Drainage Advisory Group, will have to spend $3 for on-farm and areawide facilities for each $1 spent on the master drain facilities. After such expenditures, the farmers may not have any payment capacity for repayment of the master drain. It appears that if the entire burden of repayment is borne by the farmers in the drainage problem areas, there will not be a valleywide master drain.

There are other beneficiaries of the project and contributors to the salt management problems of the Valley. The other beneficiaries primarily are taxpayers at the county, state, and national levels. The other contributors to the problem primarily are other water users and waste dischargers in the drainage basins of the San Joaquin Valley. As in the case of municipal waste treatment, these other beneficiaries represent such a broad spectrum of society that assistance under PL 92-500 appears warranted.

Repayment becomes a social or political problem because the other

contributors to the Valley's salt management problems and the other beneficiaries of the Valley's salt management system do not fully recognize their interest in a solution to the Valley's salt management problems. A second major social or political problem relates to the location of the "salt sink" that is utilized in the solution to the problem. Opposition has been expressed in the San Francisco Bay area and at all proposed points of discharge into the Pacific Ocean. Inland evaporation also has been critized and opposed.

This bulletin does not propose a specific plan for repayment. It does present for public discussion possibilities for repayment, and does imply that repayment should be an obligation of the farmers in the drainage disposal problem areas, the people and/or governmental agencies in the San Joaquin Valley, and the state and national governments.

Conclusions

1. There cannot be effective management of the surface and ground water resources of the San Joaquin Valley without a valley salt management system.

Such a system would consist of three basic elements: (a) the on-farm facilities to capture the potentially damaging subsurface waste waters, (b) the areawide or district collection facilities that would collect the waste waters from the on-farm systems, and (c) the main disposal facilities or master drain.

2. The main disposal facilities should be an integrated system of works to provide for effective salt management in the San Joaquin Valley. While component parts of such a system might be constructed by federal, state, and local agencies, the components must be operated in a manner that in effect provides a single integrated system.

3. In addition to farmers in the drainage disposal problem areas, there are legitimate regional, state, and national interests that will be served by the construction and operation of a San Joaquin Valley salt management system. The protection of the interests of the people of the region, state, and nation should be reflected in any repayment plan for such a system.

4. The federal San Luis Drain should be an integral part of a San Joaquin Valley salt management system. The San Luis Drain should be completed by the U.S. Bureau of Reclamation and should be used to maximum capacity to provide drainage service on an interim basis to lands between the federal San Luis Unit service area and its terminous.

5. Results of nitrogen removal treatment studies by the Department of Water Resources, the U.S. Bureau of Reclamation, and the federal Environmental Protection Agency show that several processes are available to remove the biostimulatory effects of valley tile drainage waters on potential Delta receiving waters. An Environmental Protection Agency conclusion (based on its regrowth studies) is:

> "The bioassay responses of mixtures of treated agricultural drainage with San Joaquin River water showed that nitrogen removal from agricultural drainage is definitely effective in reducing biostimulation."

6. The federal San Luis Drain should discharge at a point near Antioch Bridge. Such a discharge should be made as early in time as is possible, so that a precise evaluation of the impacts of an agricultural waste water discharge in the western Delta area can be made under all conditions of tide, net outflow, and quality that exist in the western Delta channels throughout a year. An ideal time for such evaluations will exist over the next 10 to 15 years, when there will be relatively low drain flows and adequate storage capacities for control of those drain flows. The evaluations will provide a basis for determination of the need for nitrogen removal treatment and/or extension of the drain to a more westerly discharge point.

7. The use of agricultural waste water for power plant cooling could reduce the volume of waste water requiring final disposal by up to 90 percent. The total quantity of salts, however, would remain virtually unchanged--with up to a ten-fold increase in brine salt concentrations. Careful disposal of the brines would have to be an integral part of any use for power plant cooling.

8. A method must be determined to assure repayment of reimbursable costs for a salt management system that will equitably assess costs in proportion to benefits from such a system. All studies related to financing and payment should consider the possibilities of funding available under the State's Clean Water Bond Act and the National Pollution Discharge Elimination System of PL 92-500.

CHAPTER II. THE VALLEY ENVIRONMENT

The San Joaquin Valley is walled by the Sierra Nevada on the east, the Coast Range on the west, and the Tehachapi Mountains on the south. The valley floor is about 300 miles long and averages about 40 miles wide. It contains about eight million acres, almost all below an elevation of 500 feet. The valley floor slopes gently from the eastern and western foothills to the north-south-trending trough located in the western third of the Valley. The valley trough slopes gently from south to north and drops from an elevation of about 300 feet in Kern County to sea level at the Sacramento-San Joaquin Delta.

Most streamflow enters the Valley from the Sierra Nevada on the east. Between the Kings and San Joaquin Rivers, the gentle northward slope of the valley floor is interrupted by a low divide that prevents draining of the surface waters from the southern portion into the northern part.

The area south of the divide is called the Tulare Lake Basin, and that north of the divide the San Joaquin River Basin. The nearly imperceptible divide rises to only about 25 feet above the lowest point in the Tulare Lake Basin, the Tulare Lakebed.

The Predevelopment Valley Environment

Before development, the valley floor was dominated by vast lakes and swamps surrounded by tree-dotted grasslands. The huge lakes--Kern, Buena Vista, Goose, and Tulare--were replenished annually by the flows of the Kern, Tule, Kaweah, and Kings Rivers in the Tulare Lake Basin. Excess waters of Tulare Lake Basin flowed over the divide at the north and joined the San Joaquin River near the present City of Mendota. A major swamp covered the central area of what now is Merced County. The waters of the San Joaquin, Fresno, Chowchilla, Merced, Tuolumne, and Stanislaus Rivers flowed to the trough of the Valley and then northward and westward via the San Joaquin River through the Sacramento-San Joaquin Delta and San Francisco Bay to the ocean.

Early settlers found grizzly bears, pronghorn antelope, and Tule elk, as well as numerous other animals, warm-water and anadromous fish, water birds, and both resident and migratory waterfowl.

Resident valley Indians had established relatively permanent settlements on the valley floor because of the abundance of wildlife and plants which provided food and shelter. Some tribes apparently wintered in the Valley and spent summers in the mountains, while others apparently lived year-round on the valley floor and hunted in the foothill and mountain areas.

The Change in the Valley Environment

Settlers began to arrive in the Valley and establish homesteads in about 1840. The mining boom of 1849-50 was followed by the development of farming as the demand for agricultural produce and livestock increased with the rising population. Sheep and cattle were grazed extensively on the valley floor. Mexican land grants were purchased and large land empires developed. Bonanza crops of wheat were grown in the 1860s. By the end of that decade, however, livestock grazing was limited because the native grasses on the valley floor had been destroyed

by overgrazing and wheat farming. The end to the open range came in 1870, when the California Legislature enacted a law requiring owners to fence their livestock or pay for crops damaged by their animals.

At first, lands adjacent to streams were irrigated with water diverted by individuals. This phase was followed by a period where canals were built through cooperative efforts of groups of farmers as water was required to develop areas more distant from streams. Still later, stock companies were formed to finance larger irrigation systems, and by the late 1880s several systems had been developed on the east side of the Valley for diversion and distribution of river flows for irrigation.

The Federal Government had deeded some 2 million acres of Central Valley swamp lands to the State under the Swamp Land Act of 1850, and in 1857 the State offered patents to those who would drain and reclaim river bottom lands. In 1874 a large area of overflow land was patented near Bakersfield.

In 1867, a large canal was completed from Mendota to Los Banos to divert water from the San Joaquin River for irrigation of overflow land in western Merced County that was used for livestock grazing.

Prior to the advent of railroads in the Valley, the distance to markets and the cost of transportation restricted the Valley's agricultural potential. After the railroads came in the 1870s, irrigated orchards, vineyards, and other crops became profitable. Cotton was first grown on the Kern River Delta in 1872. Introduction of irrigation also made production of a greater variety of crops possible. By 1931, more than 2 million acres (more than one-third of the total irrigated area in the State at that time) had been placed under irrigation.

Ground water was first pumped to irrigate lands not served by diversions from rivers. As ground water pumping on the east side of the Valley increased, artesian flows of ground water in the trough of the Valley began to decrease. An example of early development based on artesian ground water was a successful agricultural colony of about 30,000 acres in the vicinity of Corcoran that produced field, truck, and fruit crops, and dairy products. By 1929, the free-flowing wells had all but stopped, and pumped ground water was being used extensively in the Tulare Lakebed.

On the east side of the San Joaquin River Basin, direct surface diversions from the rivers were used until the irrigation developments became sufficiently extensive to finance foothill storage facilities on the rivers. Ground water was not pumped initially in this area for irrigation--only for drainage. Even today most of the water used for irrigation on the east side of the basin is surface water.

As irrigated development progressed on the west side of the San Joaquin River Basin, the lower-lying areas were irrigated first by gravity diversions from the river. Extension of irrigation into the higher areas depended on pumped ground water and on systems of relift pumps and canals that conveyed water diverted from the San Joaquin River.

The Valley Environment Today

The environment of the San Joaquin Valley today is a result of development and use by modern man. The vast lakes have been drained, and their bottom lands are being farmed. Only remnants of the once-predominant swamps are found in the private duck club areas

and on state and federal waterfowl refuges. The grasslands have been plowed and planted. A network of local, state, and federal roads and highways provides access to nearly all parts of the valley floor and to many areas of the surrounding foothills and mountains.

Water supplies of the San Joaquin Valley are almost completely under man's control, and only during periods of extremely heavy precipitation and major flooding does water escape the Valley without being put to use. All rivers originating on the east side of the Valley in the Sierra Nevada have reservoirs that conserve winter flows for summer irrigation use. Water from the upper Tuolumne River watershed is transported to the San Francisco Bay area through the Hetch Hetchy system. Essentially all domestic, municipal, and industrial water supplies in the Valley are obtained from ground water, although plans call for supplements to that supply from the California Aqueduct, including 100,000 acre-feet of municipal and industrial water for Kern County users.

Except for flood flows, virtually all of the water available to the San Joaquin Valley is used at least once and is often used several times. Essentially all water that enters the Tulare Lake Basin remains there. During the summer months, water in the main stem of the San Joaquin River in Merced and Stanislaus Counties is mostly agricultural waste water, irrigation return flow, and ground water seepage.

Agriculture is the dominant segment of the economy of the San Joaquin Valley. Nearly all of the people in the Valley live there because of agriculture, although a very small proportion derive their incomes from mineral extraction (primarily petroleum products) and lumber.

The Fresno City-County Chamber of Commerce describes that area as the "Agribusiness Capitol of the World". The 1973 gross return from agricultural production in the eight valley floor counties was $3.6 billion out of a state total of $7.5 billion, although the eight-county figure includes the value of some Kern and San Joaquin County crops grown outside the Valley.

In 1929, gross returns from crops and livestock products for the same eight counties were $233,220,000--about 30 percent of the total return in the State. In 1963 valley agricultural production was $1,719,000,000, and by 1968 it had increased to $2,002,000,000. During the 1960s, agricultural returns in the Valley were about half of the total for the State. In 1968, gross returns for the eight valley floor counties were greater than the gross returns for 47 of the 50 states.

Both agriculture and recreation in the San Joaquin Valley are dependent on water, and man has moved water around the Valley in response to this need.

Waters of the upper San Joaquin River are halted at Friant Dam and transported southward into Kern County in the Friant-Kern Canal--with a small part of the water moved north into Madera County. Former users of waters from the upper San Joaquin River in Fresno, Merced, and Stanislaus Counties receive a replacement or "exchange" supply from the Delta-Mendota Canal. The Delta-Mendota Canal diverts water originating largely in the Sacramento River Basin from the south edge of the Delta and transports it southward to Mendota Pool--a diversion facility on the San Joaquin River located near the City of Mendota. Friant Dam, the Friant-Kern Canal, the Madera Canal, and the Delta-Mendota Canal are all part of the U. S. Bureau of

Reclamation's Central Valley Project.

The latest major water supply facilities for the San Joaquin Valley are the partially combined San Luis Unit of the federal Central Valley Project and the California Aqueduct of the State Water Project. In the San Luis Unit, water is moved from the Delta in the fall, winter, and spring, using previously unused capacity of the Delta-Mendota Canal. This water is lifted from the Delta-Mendota Canal into the O'Neill Forebay, the lower and smaller of the two reservoirs of the San Luis Reservoir complex. Water that cannot be used within the service area of the San Luis Canal is stored in the larger San Luis Reservoir. During late spring, summer, and early fall, water stored in San Luis Reservoir is released for use in the San Luis Unit service area. By this means, about 1,250,000 acre-feet of water a year can be made available to the various districts comprising the San Luis Unit service area, which is dominated by the 600,000-acre Westlands Water District.

To supply the California Aqueduct, water is diverted at the south edge of the Delta and is conveyed southward to O'Neill Forebay. Waters not needed south of that point are pumped into San Luis Reservoir for storage. The joint federal-state San Luis Canal moves water southward to near Kettleman City in Kings County, providing water deliveries to the federal San Luis Unit service area. The California Aqueduct continues southward near the west and south edges of the San Joaquin Valley and will eventually provide nearly 1,250,000 acre-feet to agricultural water users in Kings and Kern Counties. Some very small amounts of water are provided for agriculture in Stanislaus County and recreation in Kings County. In addition, about 100,000 acre-feet of water will be provided for municipal and industrial uses in Kings and Kern Counties.

CHAPTER III. THE VALLEY'S SALT PROBLEMS

Water--even rainfall--contains minerals, or salts. The salts in water are combinations of common earth elements: calcium, magnesium, potassium, sodium, carbon, chlorine, hydrogen, nitrogen, oxygen, and sulfur.

As water flows over the surface of the earth, it picks up these common minerals; and, as it percolates through the soils to ground water, it dissolves even more and carries them in solution.

Crops and other vegetation use water, but little of the minerals, and so concentrate the salts. Municipal and industrial use also consumes water, but not much of the salts, and in addition adds salts to the remaining water.

The use of water thus inevitably degrades the remaining water supplies, but the increased salt burden carried by the water does not cause problems until it reaches a level high enough to affect subsequent beneficial use.

The San Joaquin Valley has reached the point where the amount of salt in the water is creating problems. Those problems are different in the Tulare Lake and San Joaquin River Basins, which make up the Valley, and therefore are discussed separately in this chapter.

Tulare Lake Basin

The sources and average quantities of water and "new" salts brought to the valley floor annually at about the 1990 level of development are set forth in Table 1. The table does not include ground waters because the water and salts from that source are a recirculation of existing supplies in the Tulare Lake Basin. The "salt

Salt filled soil supports only sparse growth of sugar beets. White crusts of salt remain after water has evaporated from ridges. Salts in furrows have leached downward. DWR photo 2144-12

TABLE 1

TULARE LAKE BASIN
SOURCES OF WATER AND "NEW" SALTS
AT ABOUT 1990 LEVEL OF DEVELOPMENT

Source	Average Annual Quantity	
	Water (in acre-feet)	Salts (in tons)
Precipitation on valley floor	3,420,000	90,000
Kern, Tule, Kaweah, and Kings Rivers	2,810,000	180,000
Other lesser streams and creeks	210,000	180,000
Diversions into basin		
Friant-Kern Canal	880,000	50,000
California Aqueduct	1,400,000	240,000 1/
Municipal and industrial waste water	--	270,000
Soil additives	--	600,000
Totals	8,720,000	1,610,000

1/ Assumes Peripheral Canal in operation and an average quality of 125 parts per million. Without Peripheral Canal, quality would average 285 parts per million and an additional 300,000 tons of salts per year.

level" problems related to ground water usage will require resolution in future stages (more than 50 years) of a total salt management system which would include management of water and salts in the ground water reservoir.

The table represents water and salt conditions as they are expected to be at about the 1990 level of development when full use is being made of existing import facilities. The only facility not yet in full use is the California Aqueduct, which delivered about 692,000 acre-feet in 1973. Under full contract entitlements, 1,349,300 acre-feet per year will be delivered.

The table shows that 1.6 million tons of new salts are being added to the Tulare Lake Basin each year. Since there is virtually no outflow from the basin, essentially all of the new salts remain in the soil and waters of the basin. A soil survey of 2.4 million acres in the basin during the San Joaquin Valley Drainage Investigation indicated that there

were about 330 million tons of salt in the top 20 feet of soils.

Although the 1.6 million tons of salt being added annually is a relatively small amount compared to the total salt load of the basin, the key point is that this small increment is beginning to cause problems in the producing agricultural areas. The estimated salt content of all the tile drainage waters in the Tulare Lake Basin will total about 1.1 million tons per year at about the 1990 level of development--about 70 percent of annual new salt load. A salt management system in the Tulare Lake Basin which captures all of the subsurface agricultural waste waters thus can provide a first major step toward "salt balance" in the basin.

Before water delivery by the State Water Project, about 3.1 million acre-feet of water supply was obtained from ground water for agricultural, domestic, municipal, and industrial purposes. It is estimated that as much as 500,000 acre-feet of the new supply from the State Water Project will be used as a substitute for ground water supplies, while another part of the State Water Project supply will be used to firm up existing fluctuating supplies--with no increase in irrigated acreage. It is estimated that the project will supply water for less than 200,000 acres of previously unirrigated lands.

San Joaquin River Basin

The sources and average quantities of water and "new" salts in the San Joaquin River Basin at about the 1990 level of development are shown in Table 2. The table does not include ground waters because the water and salts from that source are a recirculation of existing supplies in the basin. The salts from that source, however, do add to the "salt level" problems of the San Joaquin River Basin.

Before the federal San Luis Unit began deliveries in the San Joaquin River Basin, about 9.9 million acre-feet of water was used there annually. The major rivers and the federal Delta-Mendota Canal provided about 5.3 million acre-feet of this total, and the other 4.6 million acre-feet came from ground water. After full deliveries are made by the San Luis Unit, the annual water use will be about 10 million acre-feet. The reason for the small increase is that nearly all of the 1.25 million acre-foot delive. from the San Luis Unit will be used to replace water formerly

Excess salt in the soil of this field has severely decreased the yield of this crop of barley. DWR photo 2144-8

TABLE 2

SAN JOAQUIN RIVER BASIN
SOURCES AND QUANTITIES OF WATER AND "NEW" SALTS
AT ABOUT 1990 LEVEL OF DEVELOPMENT

Source	Average Annual Quantity	
	Water (in acre-feet)	Salts (in tons)
Precipitation on valley floor	2,340,000	60,000
San Joaquin, Fresno, Chowchilla, Merced, Tuolumne, and Stanislaus Rivers	5,770,000	300,000
Other lesser streams and creeks	230,000	130,000
Diversions into basin		
Central Valley Project	2,604,000	439,000 1/
State Water Project	6,000	1,000 1/
Municipal and industrial waste water	--	80,000
Soil additives	--	600,000
Diversions from basin		
Friant-Kern Canal	-880,000	-50,000
Hetch Hetchy Aqueduct	-450,000	-20,000
To San Joaquin County	-180,000	-10,000
Totals	9,440,000	1,530,000

1/ Assumes Peripheral Canal in operation and an average quality of 125 parts per million. Without Peripheral Canal, quality would average 285 parts per million and an additional 580,000 tons of salts per year.

obtained from the ground water supplies.

The problem of the San Joaquin River Basin is not one of salt accumulation within the basin, but rather a salt level problem in the main stem of the San Joaquin River. Table 2 shows slightly more than 1.5 million tons of salt arriving in the valley portion of the San Joaquin River Basin annually. An estimate of water and salts flowing from the San Joaquin River Basin in the San Joaquin River and an agricultural waste water drain shows an average annual outflow of 2.3 million acre-feet of water and 2.4 million tons of salts. The extra

0.9 million tons of salts undoubtedly will come from the soils and ground waters of the basin. A survey of 2.9 million acres made during the course of the San Joaquin Valley Drainage Investigation shows that there are about 150 million tons of salts in the top 20 feet of soils in the basin.

During summer and fall months, the water in the San Joaquin River--which is used principally for irrigation of lands on the west side of the river--is made up mostly of agricultural waste waters, agricultural return flows, and some inflow of ground water.

The salt load carried during these months is relatively constant. In years of normal and above-normal rainfall, the quality of water in the main stem of the river is adequate for the crops being irrigated, but in dry and critically dry years the quality degrades to the point where the river water cannot be used for some crops.

The salt load of the San Joaquin River creates problems not only within the basin but also in the Delta-Central Sierra Basin as river flows pass the salts on to users of water from channels of the southern Delta.

The water quality problems of the main stem of the San Joaquin River are described in detail in the Department of Water Resources Bulletin No. 143-5, "Lower San Joaquin River Water Quality Investigation", dated August 1969.

Valley Drainage Disposal Requirements

The previous two sections have described the salt problems of the Tulare Lake and San Joaquin River Basins from a regional viewpoint.

Another perspective is that of the individual farmer or public drainage agency--a local viewpoint of the drainage problem and the overall impact on the San Joaquin Valley.

Local drainage problems occur when restricting subsurface layers of soil prevent the free downward movement of

Excessive concentrations of salt in the soil of this field have almost completely prevented the growth of sugar beets. DWR photo 2144-11

excess applied water, or where the main ground water table is relatively close to the surface of the ground. Part of the problem in the San Joaquin Valley occurs when excess applied water from upslope areas flows downhill, builds up shallow ground water tables in lower-lying areas, and encroaches upon the root zone of crops being grown there.

Several methods are being used in the San Joaquin Valley to alleviate these local drainage problems, all of which are designed to remove the waters from the crop root zone or to intercept the waters before they get there. Wells are used in more permeable soil areas to lower the water table. Deep ditches are used both as interceptors and to lower the water table in areas with suitable soil structure. The most commonly used method in more dense soils is the so-called tile drain. The tile drains were so named because they were originally made of lengths of clay pipe or tile pipe. Concrete pipe later began competing with clay pipe, and today several other rigid and flexible types of pipe are used.

The tile drains are placed at a depth of 6 to 8 feet below the surface of the fields, and the water collected flows by gravity to an outlet or to a sump with a pump. Tile drains are often installed with an initial spacing of 800 to 900 feet to permit the addition of other lines in the future at eventual spacings of 150 to 200 feet. Tile drains are also used as a method of intercepting upslope underground flows.

Shortly after extensive irrigation from rivers began on the east side of the San Joaquin Valley, high water tables created agricultural production problems. These problems have virtually disappeared because of the use of ground water as a supply or the installation of drainage wells to lower the water table.

Gravity flow tile drain discharging into drainage ditch. Flow is being measured by a gage and recorder.

Typical tile drain sump. Concrete pipe section placed on end may be 15 feet deep and may drain more than 100 acres.

Such drainage waters from the east side of the Valley are usually of a quality suitable for direct reuse for irrigation and thus are not included in the agricultural waste water disposal requirements of the Valley.

Drainage waters that are too salty to be economically reused are the "agricultural waste waters" discussed in this report. The areas where such problems can occur are limited, and in general three

conditions must exist before there can be a drainage problem:

1. Restricted downward movement of excess applied waters, either because of a restricting soil layer or a high water table of poor quality.

2. Above-average amounts of soluble salts in the soils above the restriction.

3. A full and adequate water supply for irrigation.

The first and second conditions exist on about 1.7 million acres, or nearly 25 percent of the irrigable land, in the San Joaquin Valley. The extent of these potential drainage problem areas is shown on Figure 1.

About 1.2 million acres of the potential drainage problem area are irrigated, although not all of these lands have full and adequate water supplies.

There probably are not more than about 50,000 acres of tile-drained lands in the San Joaquin Valley today, with another 100,000 to 150,000 acres on the verge of having severe drainage problems. The last known survey was made in 1968, when nearly 34,000 acres of tiled lands were found, with new installations proceeding at the rate of about 4,000 acres a year. By about the year 2000, an estimated million acres will have tile drains or other drainage systems.

Tile drainage system discharges today are estimated to be about 70,000 acre-feet per year. Between 2000 and 2020, subsurface drainage systems will produce an estimated 500,000 to 600,000 acre-feet of agricultural waste waters annually. The estimated total quantities of agricultural waste waters generated in subsurface drainage systems are shown in Table 3 by counties. The

Figure 1 - AGRICULTURAL WASTE WATER PROBLEM AREAS

TABLE 3

ESTIMATED ANNUAL AGRICULTURAL
WASTE WATER DISPOSAL REQUIREMENT
BY COUNTY
(in 1,000 acre-feet)

County	Year between 1980 and 1990	1990 2005	2000 2020	2010 2035	2020 2050
Contra Costa	6	9	10	10	10
San Joaquin	11	19	24	26	28
Stanislaus	13	23	28	29	29
Merced	35	58	67	74	77
Madera	3	4	5	5	5
Fresno[1/]	64	101	105	106	108
Kings[2/]	49	70	89	89	89
Tulare	4	8	15	15	15
Kern	15	26	58	60	60
Subtotal	200	318	401	414	421
San Luis Unit	20	85	135	150	150
Totals	220	403	536	564	571

1/ Excludes disposal requirement from San Luis Unit service area.

2/ Excludes disposal requirement from San Luis Unit service area and includes a maximum of 40,000 acre-feet per year for Tulare Lakebed.

actual quantities placed in a valley drainage system would be somewhat less than the total generated since it is expected that from 5 to 10 percent of the total will be used to maintain waterfowl habitat. The southern portion of the Valley probably will contain some locally operated storage-evaporation ponds, which also will reduce the total volume requiring disposal.

The Valley's agricultural waste waters contain salts, pesticides, and nutrients. Over the last several years, monitored tile drainage system's salt concentrations generally have ranged between 2,000 and 10,000 parts per million--with an overall average of 4,000 to 5,000 parts per million. By the late 1970's, the average composite salt content of the tile drainage waters of the San Joaquin Valley is expected to be on the order of 7,000 to 8,000 parts per million of total dissolved solids. During about three decades, as salts are leached from the soils, the composite salt content of the waste waters is expected to drop to

between 2,000 and 3,000 parts per million.

Pesticides from subsurface tile drainage systems of the Valley were studied intensively between 1965 and 1969 as part of the San Joaquin Valley Drainage Investigation. A pesticide monitoring program has been continued on a reduced scale since 1969. There appears to be a direct correlation between the quantity of pesticides applied and the concentration appearing in tile drainage waters. The composite concentrations of pesticides in tile drainage waters have ranged generally from 100 to 400 parts per billion, about the same concentration as found in potential receiving waters of the western Delta-Suisun Bay area.

Nutrients in the form of nitrogen and phosphorus also are present in agricultural waste waters. On the basis of past and present studies, the average annual nitrogen content of agricultural waste waters is and is expected to remain about 21 parts per million and the total phosphorous content about a third of a part per million. Continued monitoring by the Department has not indicated any general trend of change in these estimated nutrient constituent concentrations.

Nitrogen-cycle computer modeling studies by the U.S. Bureau of Reclamation show that nitrogen concentrations in tile drainage will decrease to 3 to 5 parts per million over a period of 20 to 40 years. The dominant source of nitrogen in tile drainage waters of the San Joaquin Valley is the "natural" nitrogen that exists in the soils. Logic indicates that the "natural", or native nitrogen in the soils of the Valley should leach out with time--resulting in lowered nitrogen concentrations in the tile drainage waters of the Valley.

The problems associated with nitrogen in San Joaquin Valley agricultural waste waters are discussed in Chapter V.

CHAPTER IV. SYSTEMS FOR SALT MANAGEMENT

A number of systems that could reduce the salt balance and salt level problems of the San Joaquin Valley were studied during the San Joaquin Valley Drainage Investigation. The objective of all systems was basically the same--to prevent the salts in agricultural waste waters from entering the soils and water supplies of the Valley. Maximum reuse of the water was also considered.

The systems studied are discussed here under three general categories--desalting, evaporation, and transportation.

The discussion in this chapter is not detailed or technical but, instead, is a broad and general description of the systems aimed at helping the reader understand the relationship between the systems and how they could help preserve the soil and water environment of the San Joaquin Valley.

The costs presented in this chapter can be considered to be only reasonable approximations of December 1974 levels. The costs are presented primarily to provide the reader with information on the relative magnitudes of the costs involved. The basic information was taken from detailed cost estimates prepared in 1963, 1968 and 1973. Engineering News Record composite construction cost indexes were used to derive multiplying factors--2.3 for the 1963 estimates, 1.7 for the 1968 estimates and 1.1 for the 1973 estimates--to arrive at the late 1974 estimates.

A Desalting System

With a projected annual quantity of 500,000 to 600,000 acre-feet of brackish agricultural waste waters being generated in about 50 years, a logical conclusion is that most of this water should be reclaimed and reused. An often-suggested method of reclamation is desalting.

The preliminary edition of Bulletin No. 127 discussed the multistage flash evaporation process as the prime desalting method, but by 1967 reverse osmosis and electrodialysis desalting processes showed more promise for brackish water desalting. In these processes, the costs are more closely related to the quantity of salt removed than in distillation, thus making them more appropriate for desalting the brackish agricultural waste water.

In 1971 the Department of Water Resources initiated a program directed toward determining the technical feasibility of desalting by the reverse osmosis process the agricultural waste waters found in the San Joaquin Valley. Several modifications of a reverse osmosis desalter pilot plant have been tested in cooperation with the University of California at the Waste Water Treatment Evaluation Facility near Firebaugh. Two reverse osmosis units furnished by the federal Office of Saline Water, now part of the Office of Water Research and Technology, also have been under test.

A key objective of the Firebaugh program is to recover for reuse as much of the agricultural waste water as possible, simultaneously reducing the volume of waste brine that must be disposed of. The ultimate goal is to reduce the brine volume as much as possible, and to accomplish this, a target of "90-percent recovery or better" has been set. For example, if 10 gallons of feed water are treated, 90-percent recovery would result in 9 gallons of reusable water and 1 gallon

of brine.

Initial testing of untreated feed water was not producing the desired results because of scaling problems. The calcium salts in the feed water were clogging the reverse osmosis units. Various pretreatments of the feed water were tried, but recovery still was not approaching the 90-percent target. It was then decided to operate an ion-exchange water-softening unit in series with the reverse osmosis desalters. The ion-exchange unit removes the calcium salts from the feed water and replaces them with sodium salts, which do not scale. Using the combination of an ion-exchange pretreatment with the reverse osmosis process, the Department is consistently able to recover up to 90 percent of the feed water, at about 6,000 parts per million as a usable product water.

The reverse osmosis desalting process usually does not remove a substantial amount of the boron. If the product water is to be reused for irrigation, either blending of the product with fresh water would be necessary or an extra step to remove boron would be required.

Although cost estimates have not been attempted because of the small size and experimental nature of the test units, the favorable technical results achieved generally indicate that the cost of desalting this agricultural waste water would be similar to other such waters of comparable salt content. The Department of the Interior, in a September 1973 report showed an estimated cost of desalting agricultural waste water from the Wellton-Mohawk District with a salinity of 3,100 parts per million total dissolved solids of $136 per acre-foot of product water at a 70-percent recovery rate. Since the composite salt content in the San Joaquin Valley eventually will reach the 2,000-to-3,000-part-per-million range, it can be anticipated that costs similar to that for the Wellton-Mohawk drainage water could be achieved. The Wellton-Mohawk desalting plant cost estimates were based on a feedwater quantity of 144,000 acre-feet per year, with 101,000 acre-feet per year recovered as 240- part per million product water.

Based upon estimated Wellton-Mohawk costs (extrapolated to December 1974), assuming that about 4 plants would be constructed when drain flows dictated a need, and using projected quantities of flow in a valley master drain; the present worth of the capital costs for desalting valley agricultural waste waters would be about $185 million. The present worth of operation and maintenance costs (excluding energy) would be about $175 million. The estimated capitalized cost of energy today would be about $100 million--bringing the total costs of desalting to about $460 million. These costs cover only the cost of the desalting plant and its operation and maintenance. The cost of transporting agricultural waste waters from the farms to the desalting plant and the cost of brine disposal would be in addition to this cost.

Evaporation Systems

Considering the broad geographic span of drainage problem areas in the Valley--extending from north of Tracy to south of Bakersfield--one natural conclusion might be that evaporation of the agricultural waste waters would be a simple and cheap method of disposal. But when studied in relationship to the basic objectives of keeping the salts in the waste waters out of the soil and water of the San Joaquin Valley, the evaporation method becomes both complex and costly.

Extensive studies were made of evaporation basins on the valley floor,

evaporation-waterfowl management areas on the valley floor, a natural salt sink above the southwest corner of the Valley, and a man-made salt sink in the foothills on the west side of the Valley. With an average net evaporation rate of about 4 feet a year, about 125,000 acres of evaporation ponds would be needed to dispose of 500,000 acre-feet of water a year. This theoretical area would have to be somewhat larger in practice because the evaporation rate decreases as the salinity increases.

For example, by the time salinity reaches about 300,000 parts per million (roughly ten times sea water concentrations), the evaporation rate decreases to about 70 percent of the rate for fresh water. At slightly greater concentrations a scum of salt crystals forms on the water surface and reduces the evaporation rate to essentially zero. Wind stirring of the evaporation pond surface or some other means of breaking up the salt crystal scum is necessary for further concentration.

It has been suggested that salts might be produced for sale to reduce the costs of an evaporative pond system. During the San Joaquin Valley Drainage Investigation, several inquiries were made of commercial salt producers regarding possible markets for salts produced from agricultural waste waters. Their responses indicate that salt is a low-profit product in a highly competitive market, with production capacity and distance to market key factors.

Because of the distance from the San Joaquin Valley to major industrial users of salt, it is unlikely that salts produced in the Valley could compete with salts from other sources.

Tulare Lake Basin Evaporation

Because the southern part of the San Joaquin Valley is so far from saline estuarine waters or the Pacific Ocean, and because agricultural waste waters from there will be more saline than those produced farther north, a detailed study was made of evaporation basins in western Kings and Kern Counties.

A field investigation located nine presently undeveloped sites varying from 580 to 22,600 acres and totaling the estimated 70,000 acres that would be required to dispose of the agricultural wastes from Tulare Lake Basin. The sites had infiltration rates ranging from 0.0001 to 0.01 foot per day.

Evaporation ponds have a distinct economic advantage in that they can be constructed in stages as the quantity of agricultural waste water increases, thus avoiding a commitment of capital in advance of need.

The primary disadvantage of ponds is that, without special treatment to eliminate infiltration, some of the water will percolate into the soils and ground water beneath the ponds and add to the salt management problems of the Valley.

For the specific case studied, the facilities would consist of 70,000 acres of evaporation ponds to serve Kern, Kings and Tulare Counties, and a canal to the Delta to serve other drainage problem areas of the Valley.

The estimated cost of the total system, not including any special treatment to make the ponds less permeable, was estimated to be $148 million in 1963. Today the estimated cost of such a system would be about $340 million--about $230 million for capital investment and about $110 million for present worth of operation

and maintenance costs.

Waterfowl-Evaporation Plan

An offshoot of the total evaporation plan was a waterfowl-evaporation plan that would dispose of slightly more than half of the agricultural waste waters in Kings and Kern Counties. Under this plan, a 38,000-acre area of privately owned duck club lands, federally-managed wild waterfowl lands, and state-managed waterfowl lands would be developed in northern Kern and southern Kings Counties. The State would add 22,000 acres to both the existing 11,000-acre Kern National Wildlife Refuge and the 5,000-acre Lurline Gun Club area.

Waste waters from south of the site and adjacent areas would be brought to a regulatory reservoir located within the developed area. The waste water would be delivered from the regulatory reservoir to the federal, state, and private lands as a water supply for waterfowl habitat maintenance. After use, interior drains would convey unconsumed water to an evaporation basin for final disposal.

The remaining waste waters in the Tulare Lake Basin--primarily from the Tulare Lakebed--and agricultural waste waters from areas north of Kings County would be conveyed by canal to the Delta.

The 1963 estimated cost of the total system, not including any federal or private investment to make use of the agricultural waste waters, was $112 million. In 1974 the equivalent cost of the system would be about $260 million--about $210 million for capital investment and about $50 million present worth of operation and maintenance.

The primary advantage to the proposal is that about 22,000 additional acres would be dedicated to waterfowl habitat, and would help preserve the integrity of the Pacific Flyway. The primary disadvantage is that some of the salts in the agricultural waste waters would percolate into the soils and ground waters underlying the evaporation-waterfowl habitat area.

Carrizo Plain Evaporation

There is a natural sump about 1,400 feet above and adjacent to the southwest corner of the valley floor--a closed basin known as the Carrizo Plain, which is shown on Figure 2. The basin, which contains a salt water body called Soda Lake (shown on Figure 1), is located in the Coast Range of San Luis Obispo County about 30 miles west of Buena Vista Lakebed. The Carrizo Plain is a closed basin, which, if full, would flow into the Upper Salinas River basin. Most of the land in the plain is used for dry-farmed wheat and cattle grazing. Some of the lands adjacent to Soda Lake are subdivided, but there are relatively few improvements.

The plain could be used to store all agricultural waste waters from the San Joaquin Valley in the area south of Gustine--including the federal San Luis Unit service area. The complete salt management system would include a canal to convey waste waters generated in areas north of Gustine to the Delta.

Cost estimates were prepared in 1963 on the assumption that all tile drainage waters south of Gustine would be conveyed to a point where the water could be pumped through Avenal gap and over the Temblor Range into the Carrizo Plain. About 1,900 feet of pump lift would be needed to move the water from the valley floor to the disposal area. Under this plan, the Carrizo Plain would become another "Salton Sea" in California. It would have a maximum depth of about 150 feet and a surface

area of about 80,000 acres. This salt management system would be very expensive. In 1963 the estimated total capitalized cost was $437 million--about 40 percent of which was for electricity for pumping. In December 1974, the total system costs would be about $910 million--with $305 million for pumping energy, $130 million as present worth of operation and maintenance costs, and $475 million for capital investment.

The Carrizo Plain could be used, of course, to dispose of lesser quantities of water that will be generated in Kings and Kern Counties. The costs, however, would be relatively high because of the pump lift required to move the waste waters from the San Joaquin Valley floor, over the Coast Range, and into the plain.

Panoche Valley Evaporation

During the San Joaquin Valley Drainage Investigation, Fresno County officials suggested that use be made of potential reservoir sites on the west side of the San Joaquin Valley. The County's Director of Natural Resources suggested, in particular, the use of Panoche Valley as a storage-evaporation area for agricultural waste waters.

Panoche Valley is drained by Panoche Creek and is located in San Benito County about 55 miles west of the City of Fresno (shown on Figure 2). A high earth-fill dam and a 3-mile-long saddle dam could be built to form a 3-million-acre-foot reservoir with a surface area of about 29,000 acres--nearly as large as Lake Shasta.

A pump lift of a little over 1,000 feet would be required to move the agricultural waste waters from the San Joaquin Valley floor into the reservoir. In 1963, the estimated total cost of this salt management system, including a canal from Mendota to the Delta to handle agricultural waste waters from the north half of the Valley, was $260 million--including more than 20 percent for pumping energy. Today, the system costs would be about $570 million--with about $100 million for energy, about $50 million present worth of operation and maintenance costs, and about $420 million for capital investment.

The Panoche Valley evaporation reservoir would have a limited disposal capacity. If the waste waters of the Tulare Lake Basin and the San Luis Unit service area were pumped into the reservoir, it would be full in about 15 years and would be able to handle only 100,000 to 120,000 acre-feet per year thereafter. An advantage to the plan is that there would be another "Salton Sea" available for recreation. The reservoir could be managed in a way that would preserve essentially sea water salt concentrations in the reservoir--creating a very high recreation potential.

Direct Ocean Disposal Systems

The most positive salt management systems for the San Joaquin Valley would transport brackish agricultural waste waters from the Valley to the ocean--the ultimate "salt sink". All direct routes to the ocean must overcome the barrier of the Coast Range, which is the western side of the Valley. Numerous earthquake faults would be encountered in crossing the Coast Range, the largest being the San Andreas. Provisions for minimal disruption of drainage disposal service were included in the planning designs and cost estimates for all of the direct routes to the ocean.

The only reasonable indirect route to the ocean would convey agricultural waste waters from the Kern and Buena Vista Lakebeds to brackish

tidal waters of the western Delta-Suisun Bay area. The indirect routes would utilize the natural slope of the San Joaquin Valley floor to transport the agricultural waste waters from south to north--mostly by gravity. The indirect routes to the ocean are discussed in a later section entitled "Valley Master Drains".

A number of reconnaissance studies were made of potential direct routes to the Pacific Ocean. The three most reasonable routes--one with an alternative discharge point--were studied in more detail. These routes were designated as the Cayucos, Monterey, and San Gregorio - Santa Clara Valley alignments; they are described below and are shown on Figure 2.

Cayucos Alignment

The Cayucos alignment would provide an ocean disposal system for agricultural waste waters from Stanislaus County to Kern County. The complete system would include supplemental canal to the Delta providing service in San Joaquin and Contra Costa Counties.

Agricultural waste waters from Stanislaus through Kern Counties would be collected in a regulating reservoir adjacent to Avenal gap on the west side of the Tulare Lakebed. Waste waters from Kern County and a portion of Kings County could reach the regulating reservoir by gravity flow. Waste waters from Stanislaus, Merced, and Fresno Counties, and a portion of Kings County would have to be pumped in several low-lift pumping plants to reach the regulating reservoir.

The alignment would pass through Avenal gap, parallel the California Aqueduct Coastal Branch to the Polonio Pumping Plant near the town of Cholame, and then pass through the San Ysabel area to the ocean near Cayucos Point on Estero Bay in San Luis Obispo County.

The waste water would drop about 1,160 feet in 5 miles on the ocean side of the Coast Range. A 125,000-kilowatt hydroelectric power plant on the shore of the ocean would recover the power potential of this alignment.

The total capitalized cost of the Cayucos alignment was about $544 million in 1963 (including the $10 million cost of the supplemental canal) with about 30 percent of that cost paying for the net energy consumption of the system. The total costs of the system today would be about $1.16 billion--$290 million for energy, $140 million for operation and maintenance, and $730 million for capital investment.

Monterey Alignment

Under the Monterey alignment plan, all of the San Joaquin Valley agricultural waste waters from drainage problem areas south of Gustine would be conveyed over and through the Coast Range to an outfall located in or near the Monterey Bay submarine canyon--a deep offshore trench on the ocean floor. A supplemental canal discharging to the Delta would provide waste water disposal service between Gustine and the Delta.

The Monterey alignment would enter the foothills west of Los Banos, skirt the south edge of the San Luis Reservoir, tunnel under Pacheco Pass, and cross the upper Santa Clara Valley. The system would leave the Santa Clara Valley through Pajaro gap in the Santa Cruz Mountains and then parallel the Pajaro River to Monterey Bay and the submarine outfall.

The estimated total cost of the Monterey alignment was $258 million in 1963 (including the $17-million supplemental canal)--nearly 25 percent of

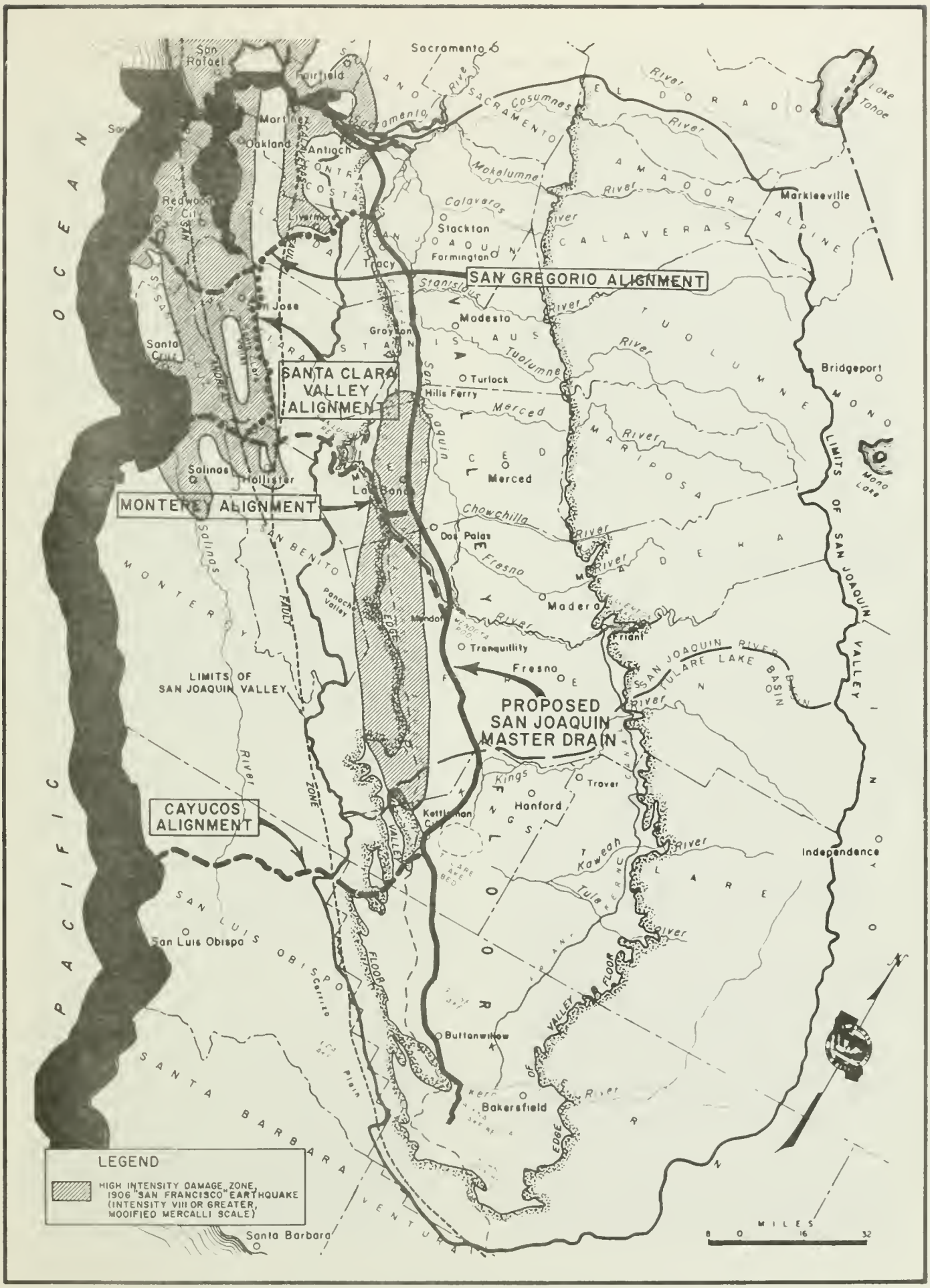

Figure 2 - MASTER DRAIN AND ALIGNMENTS TO THE OCEAN

which would be required for pumping energy. Today the total cost of this salt management system would be about $560 million;$110 million for energy, $60 million for operation and maintenance, and $390 million for capital investment.

Analyses of the power recovery potential of this salt management system in 1969 showed that it was not economical to install a power recovery plant on the ocean side of the Coast Range because there are no short, steep drops along the alignment. Despite recent sharp increases in power costs, it probably still is uneconomical to install power recovery plants in this system.

San Gregorio-Santa Clara Valley Alignments

Under both plans, agricultural waste water disposal service would be provided for all drainage disposal problem areas in the San Joaquin Valley south of Contra Costa County. In addition, the systems would have a municipal and industrial waste water disposal capacity of 50 cubic feet per second for the Livermore Valley and 300 cubic feet per second for the Santa Clara Valley.

The alignment would begin in the Valley near Kern and Buena Vista Lakebeds in Kern County and would have the same alignment as the Master Drain to near the San Joaquin-Contra Costa County line. From that point, the valley agricultural waste waters would be raised about 900 feet to a point on the eastern edge of the Livermore Valley. The waste waters would flow by gravity across the Livermore Valley and through a tunnel in the ridges at the west end of the Valley. At the first point of addition of municipal and industrial waste waters in the Livermore Valley, the conveyance facility would be changed from an open, concrete-lined canal to a large pipe or pipes. The remainder of both alignments would be in closed conduits.

The alignments would diverge shortly after leaving the tunnel from the Livermore Valley. The Santa Clara Valley alignment would follow the edge of the foothills on the east side of the Santa Clara Valley and would flow by gravity through Pajaro Gap to the Pajaro River and out to the Monterey Bay submarine canyon. The alignment from the Pajaro Gap to the Monterey submarine canyon would be the same as in the Monterey alignment.

The San Gregorio alignment would extend around the south end of the San Francisco Bay to a point opposite the town of San Gregorio--located on the ocean side of the Santa Cruz Mountains. The waste waters would be lifted another 1,000 feet, would flow down the ocean side of the Santa Cruz Mountains, and would discharge into the ocean through a submarine outfall near the town of San Gregorio.

The Santa Clara Valley-San Gregorio alignments are the most expensive of the direct routes to the Pacific Ocean. They would dispose of nearly all of the San Joaquin Valley agricultural waste waters and also would provide capacity for disposal of up to 350 cubic feet per second of municipal and industrial waste waters from the Livermore and Santa Clara Valleys.

The Santa Clara Valley alignment had an estimated total cost of $626 million in 1963--with about 23 percent of the cost required for pumping energy to lift the waste waters from the San Joaquin Valley floor to the Livermore Valley elevation. The costs today would be on the order of $1.36 billion --$250 million for energy, $120 million for operation and maintenance, and $990 million in capital investment.

Capital costs for the San Gregorio alignment would be about $55 million less than for the Santa Clara Valley alignment, but the savings would be more than offset by a capitalized cost of power which exceeded 45 percent of the total project costs in 1963. At that time, estimated total cost of the San Gregorio alignment was $855 million. Today the total costs would be about $1.75 billion--$680 million for energy, $135 million for operation and maintenance, and $935 million for capital investment.

Valley Master Drains

A San Joaquin Valley master drain salt management system would provide an indirect disposal route to the ocean. It logically would begin in southwestern Kern County, travel generally along the north-south trough line of the Valley, and discharge into tidal waters of the western Delta-Suisun Bay area. As a system, it might include various combinations of evaporation and regulatory reservoirs and transportation facilities. It would also provide a portion of the water needed for salinity repulsion--described in Chapter VI.

San Joaquin Master Drain

The best known of the master drains is the San Joaquin Master Drain, which was to have been a joint federal-state facility to provide agricultural waste water disposal service for essentially all potential drainage problem areas in the San Joaquin Valley.

As proposed in 1965, the drain would have been built in stages with the first stage being a 188-mile canal originating at the south end of the federal San Luis Unit service area near Kettleman City and running on the west side of Fresno Slough and the San Joaquin River to an initial discharge point near Antioch Bridge. About 56,000 acre-feet of regulatory storage would have been provided along the canal in southern Merced County.

The first stage of the Master Drain would have provided drainage disposal service to the federal San Luis Unit service area and to all potential drainage problem areas from there to the Delta. The capacity of the first-stage canal at its terminus would have been between 450 and 500 cubic feet per second.

The second stage of the Master Drain would have involved construction of a second canal immediately adjacent to the first-stage canal to provide additional capacity. The terminal capacity of the dual canal would have been about 1,000 cubic feet per second, which would have provided for peak summer agricultural waste water flows from the entire Valley.

The third stage would have extended the drainage system southward from near Kettleman City to near the Kern and Buena Vista Lakebeds in southwestern Kern County. In this phase a 122,000-acre-foot regulatory storage reservoir would have been built to the south and west of the Tulare Lakebed area. A 35-foot pump lift out of the regulatory storage reservoir would have taken the agricultural waste waters to an elevation where they could flow by gravity into the dual canals near Kettleman City.

The San Joaquin Master Drain, as proposed, had an estimated total cost of $108 million in 1963. Today the same facilities would have a total cost of about $250 million--about $45 million for operation and maintenance (including less than $0.5 million for power) and about $205 million for capital investment.

The Master Drain was the least costly of the various proposals studied during the San Joaquin Valley

Drainage Investigation. The plan was not implemented by the Department of Water Resources because required assurances of repayment of reimbursable costs could not be obtained.

Federal San Luis Drain

The U.S. Bureau of Reclamation has completed about 75 percent of a facility which is essentially the first stage of a master drain--the San Luis Drain from near Kettleman City to Kesterson Reservoir in northern Merced County a few miles east of Gustine. The San Luis Drain is sized for the drainage disposal requirements of the federal San Luis Unit service area. The Bureau plans to complete the drain to Kettleman City over the next few years and to construct the outlet to the Delta after 1981.

It is physically possible for the canal from the Kesterson Reservoir to the Delta to provide drainage service for agricultural waste water generated between the federal San Luis Unit service area and the Delta.

San Joaquin Drainage Advisory Group Plan

It became obvious in early 1967 that assurances of repayment of reimbursable costs would not be forthcoming from the people of the San Joaquin Valley and that the Department of Water Resources could not begin construction of the San Joaquin Master Drain. Mr. William R. Gianelli, then director of the Department of Water Resources, so informed the Bureau of Reclamation and asked the Bureau to begin construction of the federally authorized San Luis Drain. He also asked interested and affected agencies of the Valley to review the master drain plan and to develop a plan for repayment of the State's reimbursable costs. There, thus, came into being the San Joaquin Valley Drainage Advisory Group, which, in January 1969 released its "Final Report". The letter of transmittal of that report (which is a part of Appendix A of this bulletin) states in part:

> "The final report successfully melds the widely divergent views of the group's members, alternates, and observers. The report presents a possible plan that permits a greater degree of local participation than did the earlier master drain plan. The basic plan, however, is the same as all previously imposed "best" plans--that is, the primary facility is an open lined canal or canals located near the trough of the Valley and discharging into western Delta receiving waters."

The group's transmittal letter goes on to say that the plan for repayment finally proposed was less definite than the group had expected it to be in 1967. The group suggested that state funds be made available so that provisions could be made during construction of the federal San Luis Drain for its future enlargement to a single, full-sized drainage canal to serve the entire San Joaquin Valley. The group's repayment plan suggests that eventually some combination of toll charges, taxes, and government funds will provide the best means of recovering reimbursable drainage costs.

The plan proposed by the advisory group involved more local participation in the main drainage facilities. The increased local participation would be evaporation basins which would serve as initial or interim waste water disposal systems in Kings, Tulare, and Kern Counties and which would later be used for flow regulation.

The evaporation-regulation basins would be connected to the main drain canal when their evaporative capacity

is exceeded. At that time a drainage facility would be required to carry the wastes from near Kettleman City to the Delta.

The exact alignment of the valley drain was not specified by the drainage advisory group. The group's plan shows two possible alignments through Fresno and Merced Counties. The primary facility, however, would be an open lined canal in the trough of the San Joaquin Valley extending from the Kern and Buena Vista Lakebeds on the south to the Delta tidal waters on the north.

The capitalized costs of drainage facilities to serve agricultural drainage problem areas in the San Joaquin Valley are summarized in the advisory group's "Final Report". Table 4 is a slightly modified form of the advisory group's cost summary. The figures in the table are based on 1968 levels of construction costs.

The estimated costs of the Drainage Advisory Group's master drain today would be about $205 million; about $30 million for operation and maintenance (including less than $0.5 million for power) and about $175 million for capital investment.

TABLE 4

SUMMARY OF COSTS OF DRAINAGE FACILITIES
TO SERVE DRAINAGE PROBLEM AREAS IN THE SAN JOAQUIN VALLEY

Facilities	Capitalized Costs[1] (in millions of dollars)	Percent of Total Costs
On Farm[2]	318.1	68.0
Collection[2]	33.7	7.2
Master Drain	116.1	24.8
Federal	46.1	9.9
State[3]	50.1	10.7
Local[4]	19.9	4.2
Totals	467.9	100.0

1/ Present worth of all costs--capital investment, operation and maintenance, and power.

2/ Includes federal San Luis Unit service area.

3/ Includes regulating reservoir.

4/ Evaporation ponds constructed by local entities.

A salt management system for the San Joaquin Valley consists of three basic elements: (1) on-farm facilities (expected to be predominantly tile drains), (2) area-wide collection systems to move the drainage waters from the farms to the main disposal system, and (3) the main disposal system. As shown in Table 4, two-thirds of the total cost of a valley salt management system would go for construction, operation, and maintenance of the on-farm facilities. The combination of on-farm facilities and the collection facilities would account for 75 percent of the total costs, with the remainder needed for the main disposal system or "master drain". The Department of Water Resources has assumed that farmers in the drainage problem areas would pay all of the costs of the on-farm facilities and the areawide collection facilities.

Extensions West of Antioch Bridge

In the preliminary edition of Bulletin No. 127, a location near Antioch Bridge was considered to be the most easterly practicable point of discharge for the San Joaquin Master Drain. Because of the possibility that the Master Drain might have to be extended westward, cost estimates were prepared for extensions to a series of points in the Delta-San Francisco Bay area. On the basis of 1963 cost estimates extrapolated to 1974 levels, the total costs of extending the drain westward from Antioch Bridge would be about $80 million to Chipps Island, $110 million to Middle Point, $170 million to Martinez, and $270 million to near Rodeo on the west side of the Carquinez Straits.

Costs of Salt Management Systems

The total costs of the various agricultural waste water disposal systems discussed in this chapter are shown in Table 5.

The San Joaquin River as a Main Disposal Channel

Because the San Joaquin River is now used for the disposal of agricultural waste waters and return flows, many persons have suggested that the river continue to be used in this manner.

The San Joaquin River is a source of water supply for tens of thousands of acres within the San Joaquin Valley. In addition, the quality of water in the river as it enters the Delta at Vernalis is the key factor affecting the quality of agricultural water supplies in the southern Delta. San Joaquin River flows are the primary source of water in Old and Middle Rivers and on the main stem of the San Joaquin River through Stockton.

The average quality of San Joaquin River water has slowly but steadily worsened since World War II and has reached the point where, in drier years, it cannot be used for irrigation of orchard and truck crops. If the San Joaquin River were used an an agricultural waste water disposal channel, it would become worthless as a source of irrigation water in all but the wetter years.

Therefore, the use of the San Joaquin River as an agricultural waste water disposal channel is unacceptable because it would create both economic and environmental chaos on the west side of the San Joaquin River from Gustine to the Delta and in that portion of the Delta dependent on the river as a source of irrigation water supply.

TABLE 5

TOTAL SALT MANAGEMENT SYSTEM COSTS[1/]
(in Millions of Dollars)

Disposal System	Total Costs	Cost Components		
		Power	Operation & Maintenance	Capital Investment
Desalting	460[2/]	100	175	185
Evaporation				
Tulare Lake Basin	340	---	110	230
Waterfowl-evaporation	260[3/]	---	50	210
Carrizo Plain	910	305	130	475
Panoche Valley[4/]	570	100	50	420
Direct Ocean Disposal				
Cayucos	1,160	290	140	730
Monterey	560	110	60	390
Santa Clara[5/]	1,360	250	120	990
San Gregorio[5/]	1,750	680	135	935
Valley Master Drains				
1965 Proposals	250	0.5	44.5	205
Advisory Group Plan	205	0.5	29.5	175
Westward Extensions[6/]				
Chipps Island	+80	+ 8	+ 7	+65
Middle Point	+110	+10	+10	+90
Martinez	+170	+14	+11	+145
Rodeo	+270	+30	+15	+225

1/ To be used for relative comparisons only. All costs are present worth of future expenditures as of December 1974.

2/ Costs for desalting plants only. A complete system would include costs of transporting waste waters from farms to plants and the costs of brine disposal.

3/ Not including federal or private investment to make use of waste waters.

4/ Panoche Valley reservoir would fill in about 15 years and have limited disposal capacity thereafter.

5/ Includes 350 cubic feet per second capacity for municipal and industrial waste waters from Livermore and Santa Clara Valleys.

6/ Add to basic costs of a valley-wide system discharging near Antioch Bridge.

CHAPTER V. NITROGEN REMOVAL TREATMENT

In 1965 the U. S. Bureau of Reclamation and the California Department of Water Resources were actively working toward construction of a joint-use federal-state master drain for the San Joaquin Valley. While there seemed to be agreement among agencies and groups that a drainage project was needed to permit the agricultural economy of the Valley to continue to prosper, there were differing views about the effects of an agricultural waste water discharge on the quality of western Delta-San Francisco Bay waters.

Because of this lack of agreement on drain discharge effects, the Federal Water Pollution Control Administration (now a part of the federal Environmental Protection Agency) turned its Central Pacific Basins Project to a detailed investigation of the complex issue from late 1965 through 1966. The FWPCA issued a report in January 1967 entitled "San Joaquin Master Drain--Effects on Water Quality of San Francisco Bay and Delta". The report summarized the findings of the study and provided a basis for a series of interagency studies that began in mid-1967 and ended in late 1973.

The FWPCA report contained ten conclusions and eight recommendations covering both the effects of the drain discharge and certain aspects of the Master Drain's construction, operation, and maintenance. The following points are from the conclusions and recommendations of the FWPCA report:

1. Drain discharge waters could improve or worsen the Delta receiving waters, depending primarily on the quality of the receiving waters at the discharge point--which is in turn dependent on the amount of net Delta outflow. Drain waters discharged at all points in the western Delta-Suisun Bay area will help repel salt water intrusion into the western Delta channels, but at more easterly points the discharge could degrade the quality of the Delta receiving waters. Generally, where receiving waters have a concentration of a dissolved mineral salts equal to or greater than that of the drain waters, the drain discharges will have no significant effect on the saline concentrations of the receiving waters.

2. If the drain collects only subsurface tile drainage, the drain discharge would not change the concentration of pesticide residues in the Delta waters since residue levels in both tile drain and Delta waters have been essentially the same. The FWPCA report specifically recommends that " ... surface drainage (tailwater) from irrigated lands be excluded from the Master Drain because of its relatively high pesticide content."

3. An FWPCA report conclusion is that "The Nitrogen content of the Master Drain waters would, if discharged untreated at Antioch, stimulate the growth of large quantities of planktonic algae and other aquatic plants in the receiving waters." Another conclusion states that "The detrimental effects due to nitrogen in the drain waters could be prevented by treatment which would keep the nitrogen content of the receiving waters from exceeding 2 milligrams per liter." It can be concluded, therefore, that the primary potential problem-causing constituent of the

San Joaquin Valley agricultural waste waters is nitrogen.

4. The FWPCA report stated that several effective methods of treatment of drain water to remove nitrate-nitrogen showed promise of economic justification (At least 95 percent of the nitrogen in tile drainage is in the form of nitrate.) The FWPCA report recommended that joint interagency studies be vigorously pursued with the primary objective of establising the economic feasibility for nitrogen removal treatment of drain waters.

The report also noted that the FWPCA, the Office of Saline Water, the Bureau of Reclamation, and the Department of Water Resources had initiated the recommended interagency studies related to nitrate-nitrogen removal treatment, with the hub of activities at the Waste Water Treatment Evaluation Facility located near Firebaugh in northwestern Fresno County.

Fifteen reports on various aspects and phases of the work involved were to have been written. Ten reports have been published by the EPA, to date, as part of its Water Pollution Control Research Series under the EPA Number 103030 ELY series. The series has a subtitle of "Bio-Engineering Aspects of Agricultural Drainage--San Joaquin Valley, California". They also are identified by a Department number, DWR 174 series, and a Bureau of Reclamation number, REC-R2 series. This bulletin presents only a brief summary of the biological treatment methods studied, together with costs and results.

Initially, two basic processes for nitrate-nitrogen removal were studied--algal growth and harvesting, and bacterial denitrification. After the studies, an evaluation of certain data from the two processes showed that a symbiotic system involving both algae and bacteria would be as effective and much less costly than either system alone. The symbiotic study started at the end of the first study and continued for another three years.

For all of the systems, unit costs are based upon a design capacity of 228 million gallons per day--between 150,000 and 170,000 acre-feet per year. That capacity would meet the agricultural waste water disposal requirements of the entire San Luis Unit service area. To treat the drain flows for the entire San Joaquin Valley, a plant with a design capacity of about 700 million gallons per day would be required. The total cost of treatment presented in this bulletin is based upon the predicted flows of the San Joaquin Master Drain.

In reading about the treatment processes, two points should be kept in mind. First, nitrogen removal treatment would be needed only for salt management systems that would discharge into the Delta-San Francisco Bay area. Second, treatment may not be needed to protect the receiving waters because nitrogen probably is not now the limiting factor related to algae growth and computer model studies indicate that nitrogen concentration in tile drainage effluents will decrease to 3 to 5 milligrams per liter as "native" nitrogen is leached from the soils.

Nitrogen in Delta-Bay Waters

In contrast to conclusions in the January 1967 FWPCA report, most authorities now agree that nitrogen is not presently an element limiting undesirable biologic growth in the Delta. While the factors controlling biologic production are complex, the June 1969 final report of the San Francisco Bay-Delta Water Quality Control Program reported that total nitrogen and phosphorus concentrations are from

ten to one hundred times greater in the Delta than those reported necessary for substantial growths of algae. A conclusion in that later report is that, at the present time, the growth-limiting factors almost certainly are light availability and/or the presence of toxic or inhibitory materials in the waters.

The 1965 nitrogen loads reaching San Francisco Bay totaled 211 million pounds, of which agricultural drainage accounted for 23 million pounds or 11 percent. The total load is expected to reach 864 million pounds by 2020, of which agricultural drainage would contribute about 51 million pounds--or 6 percent. Of this, the San Joaquin drainage facilities would contribute about 23 million pounds--about 3 percent of the total.

At present, it appears feasible to discharge agricultural tile drainage to the Bay-Delta system, on a trial basis, without creating additional undesirable biologic growth in the system.

Algal Growth and Harvesting Process

The concept of algal growth and harvesting is relatively simple--(1) grow algae in the agricultural waste waters, which supply nitrogen for the growth process, and (2) harvest the algae, thus removing the nitrogen from the agricultural waste waters. This process has often been referred to as the "algae stripping" process.

Algae stripping will reduce nitrogen concentrations of the San Joaquin Valley agricultural waste waters to a level of 3 to 5 milligrams per liter, see Table 6. It is a relatively high cost method. Based on 1969 cost levels, the estimated unit cost, including the capital investment and operation and maintenance, was $177 per million gallons. The algal by-product had an estimated market value of about $60 per ton, or $42 per million gallons. The net unit cost of the algae stripping method, therefore, was about $135 per million gallons, or approximately $45 per acre-foot. The total capitalized cost would have been about $115 million. Today, those costs would be closer to $70 per acre-foot and $240 million.

A key consideration in selection of any treatment method is the amount of land required. Facilities for the algal stripping process would require more than 30,000 acres of land at the full capacity of the Master Drain. Even though the algae produced would have a greater protein content than any crops that could be grown on these lands, the potential impact of the conversion from agriculture to aquaculture would have to be carefully evaluated.

Bacterial Denitrification

Bacterial denitrification is a process which uses bacteria as the key biological agent. An environment without free oxygen is created, and the growth of bacteria that use the chemically combined oxygen is encouraged. The bacteria reduce the nitrate ions in the waste waters to nitrogen gas, which escapes to the atmosphere. A source of organic carbon must be added to the agricultural waste water to encourage growth of the bacterial colonies.

In the treatment studies at Firebaugh, methanol was used because it was the easiest to obtain, cheapest, and most readily controllable source of organic carbon at that time. Because the production of methanol requires large quantities of energy and energy-producing resources, that situation may not be true today. There are, however, numerous sources of organic carbon which could be used to encourage the growth of nitrate-reducing bacteria.

At Firebaugh, two anaerobic process configurations were studied--deep

TABLE 6

COMPARISON OF ACCOMPLISHMENTS AND COSTS
OF NITROGEN REMOVAL TREATMENT PROCESSES

Studied at the
Waste Water Treatment Evaluation Facility
near Firebaugh, California

Process/Configuration	Accomplishment--Total Nitrogen in Effluent[1] (in milligrams per liter)	Unit Cost[2] (in dollars per acre-foot)	Total Capitalized Cost (in million dollars)
Algal stripping/Ponds	3-5	70[3]	240
Anaerobic/Ponds	2-4	47	160
Anaerobic/Filters	2-3	47	160
Symbiotic/Algae	3-5	47	160
Symbiotic/Grass	3-5	20	70
Symbiotic/Combination	3-5	25	85

[1] Total influent nitrogen equals 20 milligrams per liter.

[2] Converted to December 1974 levels using a factor of 1.6.

[3] Net cost, includes cost recovery from sale of algae.

covered ponds and upflow filters. The deep covered ponds could reduce the nitrogen level of the agricultural waste waters to between 2 and 4 milligrams per liter. The range of effluent nitrogen from the upflow filters was 2 to 3 milligrams per liter.

The 1969 cost estimates indicated that the cost of the anaerobic denitrification process, using covered ponds, would be about $88 per million gallons and, with filters, the cost would be about $92 per million gallons. The anerobic denitrification process 1969 capitalized costs were about $100 million--at $30 per acre-foot. Today these costs would be about $160 million--at $47 per acre-foot. The anaerobic ponds would require about 5,000 acres of land and the filter process would require less than 200 acres.

Symbiotic Process

During the course of the algae stripping studies, data were obtained from certain of the facilities and during certain phases of the studies

which showed that nitrogen was "disappearing" from ponds which contained little algal growth. Evaluation of the data suggested that algae and bacteria, working together (symbiosis), were the organisms probably causing the "disappearance" of the nitrogen. A theoretical analysis of the symbiotic system indicated that the cost of nitrogen removal treatment might be cut in half when compared to the anaerobic denitrification process.

Three symbiotic process configurations were studied at Firebaugh. The first utilized clean, soil-lined ponds--known as algae ponds. The second configuration had grasses planted in the ponds and were known as grass ponds. The third configuration had algal ponds followed by grass ponds and was called the combination system. In all three configurations, the reduction of nitrate by bacterial action accounted for about one-half of the nitrogen removed.

All three process configurations were able to reduce the effluent nitrogen concentration to between 3 and 5 milligrams per liter. In the algae ponds, volatile solids concentrations (a measure of algal content) were on the order of 30 to 60 milligrams per liter--only about 15 percent of the 200 to 400 milligrams per liter obtained in the high-rate algae stripping ponds. Algae also grew in the grass ponds, but effluent volatile solids concentrations were only about one-sixth of that found in the symbiotic algal ponds--5 to 10 milligrams per liter--probably because of filtering action by the grasses.

The symbiotic algae pond configuration would reduce effluent nitrogen to between 3 and 5 milligrams per liter at a cost competitive with the anaerobic denitrification process--$89 per million gallons at 1969 cost levels, or about $30 per acre-foot. Similar estimates for the grass ponds show the lowest cost of any of the three configurations--$38 per million gallons, or about $13 per acre-foot. The combination system costs are about 25 percent higher than the grass ponds--$48 per million gallons, or about $16 per acre-foot.

Today, the total capitalized cost of the algae pond configuration would be the same as the anaerobic denitrification process--about $160 million at $47 per acre-foot. The least costly configuration (the grass pond) would have a total capitalized cost of about $70 million at $20 per acre-foot. The combination system falls in between--about $85 million, $25 per acre-foot. All of the capitalized costs are based on a treatment plant with capacity to treat the flows of a valley master drain.

The total land requirements for the symbiotic process are essentially the same as the algal stripping process--more than 30,000 acres for the flows of a valley master drain. There would be some difference among the three symbiotic process configurations. Until the efficiency of full-sized ponds is determined, the differences in land requirements cannot be precisely estimated.

Regrowth Studies

The primary purpose of the interagency nitrogen removal treatment studies was to find a method or methods which would reduce the biostimulatory effects of the agricultural waste waters on the Delta receiving waters. To test the results of treatment, a series of laboratory tests was made on both treated and untreated agricultural waste waters mixed in different concentrations with western Delta waters from the vicinity of Antioch. Most of these regrowth studies were conducted by the EPA at its Alameda laboratory.

The results of the regrowth studies are contained in an August 1971 EPA report entitled "The Effects of Agricultural Waste Water Treatment on Algal Bioassay Response" (13030 ELY 08-71-9). The six conclusions of that report are set forth below:

1. San Joaquin River algal bioassay responses were related to the nitrate and algal content. Summer and early fall bioassay samples had a high initial algal growth and a low nitrate concentration; little growth occurred in the laboratory.

Winter and spring samples had a low initial algal population and a high nitrate concentration; large algal growth occurred during the course of the bioassays.

2. Mixtures of San Joaquin River water and untreated agricultural drainage consistently stimulated algal growth, regardless of the season.

3. The bioassay responses of mixtures of treated agricultural drainage with San Joaquin River water showed that nitrogen removal from agricultural drainage is definitely effective in reducing biostimulation.

4. Effluents from algal pond and anaerobic denitrification treatment systems produced statistically equal bioassay responses when compared on the basis of the nitrate and nitrite remaining in the effluent. In general, algal bioassay responses varied inversely with the efficiency of nitrogen removal. High terminal chlorophyll bioassay concentrations were associated with inefficient removal of nitrogen from the waste water.

5. When inorganic nitrogen was below 2 mg/l in treated drainage, algal growth responses of the mixture of treated drainage and San Joaquin River water produced responses similar to those of San Joaquin River controls.

6. Algal growth responses observed in untreated agricultural waste water were reproduced when nitrate-nitrogen was re-added to the treated waste waters bringing the levels back to those found in the original waste water.

It appears certain that the waters of the Delta and San Francisco Bay can be protected against nitrogen--the primary problem-causing constituent of the San Joaquin Valley agricultural waste waters--if such protection is found to be necessary in the normal environment of the Delta. All of the regrowth tests were conducted in the laboratory and do not represent normal Delta conditions.

Factors controlling algae growth in Delta waters are very complex. The June 1969 final report of the "San Francisco Bay-Delta Water Quality Control Program" indicates that total nitrogen and phosphorus concentrations are many times greater than those reported necessary for substantial growths of algae--yet substantial growths of algae generally do not exist in the Delta. The final report concludes that, at the present time, the growth-limiting factors almost certainly are light availability and/or the presence of toxic or inhibitory materials in the Delta waters.

CHAPTER VI. OTHER USES OF AGRICULTURAL WASTE WATER

The policy of the Department of Water Resources consistently has been that maximum use should be made of all waters in the San Joaquin Valley before they are wasted from the Valley. The Department's June 1966 "Criteria for Acceptance of Waste Water into the San Joaquin Master Drain" states, in part, in the policy section:

> "It is intended that all San Joaquin Valley waste waters shall be used and re-used to the maximum extent practicable before discharge into the Master Drain."

Even after water becomes unusable for conventional agriculture, it has several other potential uses.

Marsh Management

Marshlands in the San Joaquin Valley are an important part of the Pacific Flyway (a major international migratory waterfowl route) and help reduce crop depredation by the migrating birds.

Excess water and salt may be a suitable environment for wildlife habitat, but the same area must be drained before it would be suitable for agriculture. DWR photo 2151-23

Agricultural waste waters can be used for management of marshlands in the Valley to maintain the waterfowl habitat and summer grazing lands.

Wetlands in the San Joaquin Valley provide opportunity for recreation and provide habitat for wildlife. Most of the wetlands are in private ownership. Maintaining these lands as wetlands may create more benefits than would be provided by converting them to cropland.

The Grasslands Water District in western Merced County has used agricultural waste water and return flows for at least 20 years for this purpose, and with appropriate facilities, the quantities used could be increased in that area. The Kern National Wildlife Refuge and private duck clubs in Kern County also could make use of such waters if proper facilities were available.

It would be possible to convey valley agricultural waste waters to the Suisun Marsh on the north side of Suisun Bay. Because there are other possible sources of water for management of the Suisun Marsh, this alternative use was not studied in detail as part of the San Joaquin Valley Drainage Investigation.

Power Plant Cooling

The use of agricultural waste waters for power plant cooling has been discussed and studied with considerable interest over the last few years. Treatment of the agricultural waste waters probably will be required before they can be used for this purpose. The Department plans to initiate a program to determine the required treatment of the waste water in cooperation with the Richmond Field Station of the University of California. Financial participation in the program is being sought from several electric power agencies. The program includes field testing of treatment processes at a site in the San Joaquin Valley.

Inland thermal power plants annually require about 1,700 acre-feet of cooling water per 100 megawatts of generating capacity. From figures presently available, it appears that there could be at least eight electrical generating units with a total capacity of about 10,000 megawatts installed in the San Joaquin Valley by about year 1990. The cooling water requirements of those plants would be about 170,000 acre-feet per year--a potential use of over 40 percent of the agricultural waste water generated in the Valley by about 1990.

The use of agricultural waste waters for power plant cooling would reduce the volume of waste water requiring final disposal. A 90 percent reduction in the volume used for power plant cooling is a distinct possibility. The total quantity of salts, however, would be essentially unchanged. With a 90 percent reduction in water volume, there would be a ten-fold increase in salt concentration. In the Tulare Lake Basin such concentrations could range between 40,000 and 60,000 milligrams per liter. Careful disposal of the brines would have to be an integral part of any use for power plant cooling.

Aquaculture

The Valley's agricultural waste waters could be used to grow algae, fish, and other aquatic life as a source of food. In Chapter V, the algal growth and harvesting treatment process was discussed. Rather than a treatment process, it could be considered a use that would produce a high-protein algal product that could be used as (1) a poultry or livestock feed, (2) a soil conditioner, or (3) a protein source for the production of industrial adhesives. It also could be digested to produce methane gas, which has a number of potential uses. In some countries, algae are used as a protein supplement for human consumption.

The fact that fish and other aquatic life grow in agricultural waste waters and return flows is evident in all of the valley drains. Blackfish (a rough fish) were grown in small ponds at Firebaugh. The production of fish which could be converted to fish meal is a possible use of the drainage waters. In addition, edible catfish, crayfish, and brackish-water shrimp probably could be grown in such waters. As with most of the other potential uses,

research is needed to determine conditions necessary for reproduction and growth and to determine the economics of the aquacultural use.

Oil Field Repressurization

Agricultural waste waters also could be used for the repressurization of some of the oil fields in the southern half of the San Joaquin Valley. The U.S. Petroleum Laboratory in San Francisco has studied drainage waters and other potential sources of water supply for repressurization. The Petroleum Laboratory concluded that such a use of agricultural waste waters was possible, but treatment would be required before injection. The treatment would have to be tailored primarily for the different chemical and geologic conditions found in the various oil field reservoirs.

Irrigation

A variation of the symbiotic-grass pond treatment discussed earlier in this report would be the production of salt-tolerant plants that could be used as livestock fodder. Many salt-tolerant plants require a better quality of water for germination but will grow with a poorer quality water supply. The economics of such use has been marginal in the past, although there are some farming operations that use brackish oil field waste waters or brackish agricultural waste waters for irrigation. Close control of farm operations would be required for crop production and to prevent degradation of soils or ground water supplies. The planned use of the Valley's agricultural waste waters for irrigation of more salt-tolerant crops would depend primarily on the economic aspects of farming operations at a particular time.

Sea Water Repulsion

An incidental beneficial use of agricultural waste waters, that would occur outside of the San Joaquin Valley is the repulsion of sea water. The intrusion of ocean salts into the western Delta-Suisun Bay area is controlled by the quantity of net Delta outflow. The addition of valley agricultural waste waters to the western Delta could increase the quantity of net Delta outflow.

To obtain some idea of the dollar value of this potential use of agricultural waste waters, a series of runs were made on the Department's salinity intrusion model to determine the combination of fresh water releases from the eastern edge of the Delta and master drain discharges near Antioch Bridge that would provide a quality equal to that provided by the fresh water releases alone. The agricultural waste waters, because of the salt content, would not provide the same degree of quality control as an equivalent quantity of fresh water released at the eastern edge of the Delta. The model studies showed that 2 cubic feet per second of agricultural waste water would be needed to replace 1 cubic foot per second of fresh water.

Using projected flows of the Master Drain and a $10 per acre-foot value of fresh water in the Delta near the eastern edge, a total capitalized value of the fresh water that could be saved (a benefit) was calculated to be $11 million. Recent Department of Water Resources estimates of the cost of additional fresh water supplies at the Delta are on the order of $50 to $60 per acre-foot. Thus, the indicated value (benefit) of the San Joaquin Valley agricultural waste waters for repulsion of sea water would be on the order of $60 million.

CHAPTER VII. SOCIAL, ENVIRONMENTAL, AND ECONOMIC ASPECTS OF A SALT MANAGEMENT SYSTEM

Warnings of impending drainage problems in the San Joaquin Valley were issued as early as 1886 by E. W. Hilgard, an eminent soil scientist of the time.

His predictions came true in the 1890's and early 1900's as the use of surface streamflow for irrigation filled the ground water basin in numerous parts of the Valley and farm soils became waterlogged and accumulated excess salt concentrations.

With increased use of ground water for irrigation, the early-day drainage problems largely disappeared, although the legacy of salt-laden, shallow ground waters that resulted from early irrigation remains in parts of the Valley, and some lands still stand barren and useless.

About 1.7 million of the 8 million acres on the San Joaquin Valley floor can develop a shallow, saline ground water drainage problem, and about 1.2 million acres of the potential problem areas are irrigated today. Those irrigated portions of potential drainage problem areas must have on-farm drainage facilities and a system to dispose of the waste waters they produce, or the soil and water environment of the San Joaquin Valley inevitably will be degraded.

With the certain knowledge that drainage problems are developing in the San Joaquin Valley, the crucial question is whether conditions will reach a crisis stage before a "rescue operation" must be mounted or if the problems will be solved before economic disruption reaches severe proportions.

In a number of cases in the past half century, drainage problem areas have reached the point of severe economic disruption before adequate facilities for capture, collection, and disposal of drainage water were provided. In a very few cases the situation has been anticipated, and facilities have been constructed to solve the drainage problem before the economy was seriously affected.

In the San Joaquin Valley today (1974-75), it is still possible to provide solutions before the crisis point is reached. Without additional facilities, 10 to 15 years probably remain before economic disruption reaches severe proportions. With completion of planned federal and local facilities, the crisis point probably will move another decade into the future.

Repayment in Drainage Problem Areas

Drainage facilities for the San Joaquin Valley are an authorized part of the State Water Project. Among the contracting principles developed for the project is a requirement that, before construction begins, there must be assurance of repayment of the reimbursable costs--that is, the portion of the total cost considered to be the responsibility of the project beneficiaries. During 1965 and 1966, the Department tried to obtain assurance of repayment from local entities but failed for numerous and complex reasons.

Farmers directly affected by the drainage problem indicated an inability to pay all the reimbursable costs of the Master

Drain, as then being considered. Department of Water Resources economists had independently arrived at the same conclusion on the basis of classical repayment analyses which revealed that, for those farming the majority of land in the drainage problem areas, the capacity available for repayment of the costs of a master drain was negligible after they had paid the costs of the on-farm facilities, the costs of area-wide collection facilities, and the crop production costs and allowed a reasonable return on investment and allowance for farm management.

Department economists did assume, however, that the average farmer in the drainage problem area would be willing to pay a modest amount for a drainage disposal system--an assumption based on the belief that most farmers would be willing to forego a portion of their net incomes in order to protect their investments.

The "willingness to pay" was estimated to be $2.50 to $3 per acre per year. With an estimated average of one-half acre-foot per acre per year of agricultural waste water generated within the potential drainage problem areas, the willingness to pay becomes $5 to $6 per acre-foot of agricultural waste water discharged into a master drain.

The validity of this assumption was verified during one attempt to obtain assurance of repayment, when applications for drainage service at a rate of $6 per acre-foot of agricultural waste water discharged into the Master Drain were submitted by some 30 special districts in the San Joaquin Valley. The capacities requested by the districts exceeded the capacity of the then-planned first stage of the San Joaquin Master Drain.

It appears that any plan for repayment of the reimbursable costs of a drainage disposal system should include a toll charge for drainage service on either a per-acre basis or a per-acre-foot basis. The toll charge must be high enough that reusable degraded waters are not put into a drain and yet must be low enough that the farmer has sufficient monetary incentive to stay in business.

Farmers and landowners in the areas directly affected by the drainage problem are the principal beneficiaries of an agricultural waste water disposal or salt management system in the San Joaquin Valley. There are, however, others who would benefit from such a system--and it should be recognized that essentially all water using activities in the areas upslope from the problem area contribute directly to the problem.

Other Beneficiaries

Those who build and maintain structures and public works within the drainage problem area would benefit because on-farm drainage facilities would maintain shallow ground water tables at 5 or more feet below the ground surface. Without drainage facilities, ground waters would be closer to the surface, and costs of constructing and maintaining structures would be higher. Although the total savings that would result from lower construction and maintenance costs within the drainage problem area could not be estimated, the projected savings in highway construction and maintenance costs provide some measure. In 1964, the California Division of Highways estimated a capital savings (benefit) of $3 million, and the various county

road departments estimated savings of about $40 million for county roads. Benefits today would be at least twice that amount.

In addition, data provided by various mosquito abatement districts indicated that lowering shallow ground water tables would reduce marshy or swampy mosquito breeding areas; this would produce an estimated capital savings (benefit) in mosquito abatement costs of about $3 million--at 1964 cost levels.

The Department of Water Resources recognizes that not all of the drainage disposal problem areas would become totally unproductive, barren salt flats. Several attempts were made to precisely evaluate the decreases in productivity, land value, and income that would result without an agricultural waste water disposal system. All such calculations required assumptions of probable future actions on the part of the farmers and government at county, state, and national levels. It was determined, however, that there would be a minimum overall reduction of 25 percent in productivity, land value, and farm income in the drainage problem areas.

Assuming that a 25-percent reduction in property values in the drainage problem areas would be reflected in a 25-percent reduction in assessed valuation, the impact on county property tax revenues can then be calculated. In the "Final Report" of the Drainage Advisory Group, a tabulation of the estimated loss in county revenues, based on the county tax rates and assessed values during the 1967-68 fiscal year, showed that the loss would have been about $1.2 million in that year. Cities and special districts within or partly within the drainage problem area would suffer additional losses equal to three to four times the basic county revenues.

An estimate of the annual loss of state and federal income taxes was made using 1968 income levels and tax rates and assuming a 25-percent loss in net income over the drainage problem area. The results show a loss of about $500,000 in state income tax and about $900,000 in federal income tax, or a total loss of about $1.4 million a year.

Another measure of probable economic damage if there is no agricultural waste water disposal system in the San Joaquin Valley is the impact of loss in productivity on the economy of the State.

San Joaquin Valley counties account for about half of the State's total agricultural production. Although about 25 percent of the valley floor lands are in the drainage problem area, a detailed analysis in 1966 showed that, because such lands generally are planted to lower-value crops, the problem area lands account for only 16 percent of the Valley's production and thus 8 percent of the total state production.

Assuming a 25-percent loss in productivity on problem area lands if the drainage disposal system is not built, the State's gross farm income would decrease 2 percent.

In 1973 the gross farm income in California was $7.5 billion. A 2-percent loss due to decreased production in the San Joaquin Valley would have amounted to a $150-million decrease in that year.

Based on estimates by leading financial institutions that $1 of gross farm income generates an additional $4 of economic activity in

California, the impact of a $150-million reduction in gross farm income in the San Joaquin Valley would have been a $750-million reduction in the State's gross product for 1973.

Another factor that has received much attention recently is that the export of agricultural products from the United States significantly affects the effort to achieve a favorable balance of trade. In 1973, approximately $775 million worth of California agricultural products were exported to foreign countries. Figures are not available to determine the precise amount grown in the drainage problem areas of the San Joaquin Valley, although the 2-percent figure derived earlier suggests that the potential loss in exports in the problem areas could have been about $15 million in 1973.

A closely related factor that should be considered is the apparent impending world food shortage. Assuming predictions of such shortages are accurate, the loss of 25 percent or more of the productivity from 1.2 million acres in the San Joaquin Valley should not be permitted to occur.

An agricultural waste water disposal system in the San Joaquin Valley also would be a first step toward full protection of an often-overlooked resource--the ground water reservoir under the floor of the San Joaquin Valley. Without removal of salts from the soil and water environment of the Valley, the ground water reservoir will eventually degrade and the water supplies will become unusable. In 1952 the U. S. Geological Survey (USGS) estimated the available storage capacity between 20 and 200 feet below ground surface at 93 million acre-feet. In the early 1970's, the USGS reported the total usable storage capacity to be 500 million acre-feet under the Valley. This vast underground storage reservoir is important not only to the people of the San Joaquin Valley but also to all water users in California. Properly utilized, it can be a key element for water management in California.

These "other beneficiaries" of a San Joaquin Valley salt management system should assist in paying for at least a part of the master drain segment of the total system. Most of the other benefits are "savings from loss", and are very similar in concept to flood control benefits, and repayment could be assigned to a local governmental entity.

Other Contributors to the Salt Problems

Nearly everyone who uses water in the San Joaquin Valley contributes to the Valley's salt problems. Therefore, every type of development on the valley floor, and in the foothills and mountains surrounding the Valley, adds to the problems.

The type of development of concern to the farmers in the drainage problem areas is the increased irrigation of upslope lands. All evidence shows that irrigation of lands upslope from the drainage problem areas raises the shallow ground water levels in the drainage problem areas. Many of the downslope drainage problem areas were irrigated for many years without drainage problems before upslope irrigation began. In some areas, particularly between Gustine and Tracy, shallow ground water levels rose into crop root zones within a few years after extensive irrigation of upslope areas began.

Another concern is that the quality of the main stem of the San Joaquin River has deteriorated during the summer and fall months

since the end of World War II. Increasing quantities of agricultural waste waters and of agricultural return flows (tailwaters) have been major factors in this increasing problem. Another major factor is the decreased quantity of flow in the major tributaries of the main stem of the San Joaquin River due to increased storage and use of waters of the San Joaquin, Merced, Tuolumne, and Stanislaus Rivers. Thus, storage and use of waters originating in the Sierra Nevada have contributed to the increasing salt level problems of the San Joaquin River Basin.

An equitable repayment plan should include some method of assessing a portion of the costs of the San Joaquin Valley salt management system to all who contribute to the Valley's salt problems. Again this responsibility is widely disseminated and could be assigned to a local governmental entity.

Possibilities for Financing

Since the work of the San Joaquin Valley Drainage Advisory Group, several pieces of state and federal legislation have been enacted which offer potential, either directly or as precedents, for a nonreimbursable assumption of part of the costs of a master drainage system. As indicated in Chapter I, the Federal PL 92-500 enacted in 1972 provides up to 75 percent of eligible costs of municipal or public waste water treatment and disposal systems as well as requiring waste discharge permits for discharge from irrigated farm operations of 3,000 acres or more. The State Clean Water Bond Act provides an additional 12.5 percent state contribution. The federal Colorado River Salinity Control Act makes 75 percent of the eligible costs of salinity control facilities for improving the quality water in the Colorado River Basin nonreimbursable.

In summation, these acts recognize the seriousness of agricultural drainage problems and the diffuse benefits of facilities to control water quality problems. Analogous concepts are recognized in flood control measures, funded in part by federal and state contributions.

There are a number of potential sources of revenue that might be utilized to pay reimbursable costs that would not be covered by federal and state water quality control assistance funding. All of these potential sources were studied during the course of the San Joaquin Valley Drainage Investigation. The potential sources studied include:

--A unit toll charge per acre or per acre-foot of waste water discharged into the master drain;

--A unit toll charge per acre-foot of applied water, because water use is a major contributor to the Valley's salt management problems; and

--A unit ad valorem tax on land and improvements or on land only, over the entire valley, based on a benefit to the entire Valley due to preservation of the viable agricultural economy.

The financing and repayment of the cost of an agricultural drainage facility is a major obstacle in implementing a waste water (salt) management system for the San Joaquin Valley. On-farm and regional collection facilities will require an expenditure of about three dollars for every one dollar spent on a master drain. Any program undertaken to solve the Valley's drainage problems should include consideration of all funding requirements and sources--federal, state, and local.

Lush irrigated row crops grow in well-drained soils free of excess salts. DWR photo 019-2

APPENDIX A

Letter of Transmittal, Conclusions, and Recommendations
from the
San Joaquin Valley Drainage Advisory Group's
"Final Report", dated January 1969

SAN JOAQUIN VALLEY
DRAINAGE ADVISORY GROUP
P. O. Box 2385
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Joseph B. Summers,
Chairman
James F. Sorensen,
Vice Chairman
Carl L. Stetson,
Secretary

March 12, 1969

Honorable William R. Gianelli, Director
Department of Water Resources
P. O. Box 388
Sacramento, California 95802

Dear Mr. Gianelli:

I am pleased to be able to transmit to you the final report of the San Joaquin Valley Drainage Advisory Group.

In May, 1967, you asked us to review the plan and planning of the San Joaquin Valley Drainage Investigation and to develop a plan for repayment of the State's reimbursable costs for drainage facilities in the San Joaquin Valley.

The final report successfully melds the widely divergent views of the Group's members, alternates and observers. The report presents a possible plan that permits a greater degree of direct local participation than did the earlier Master Drain plan. The basic plan, however, is the same as all previously proposed "best" plans--that is, the primary facility is an open-lined canal or canals located near the trough of the Valley and discharging into western Delta receiving waters.

The plan for repayment is less definite than we visualized it would be in 1967. The Group believes that it is not politically practical or feasible to create a taxing valley-wide district in 1969. The recommended repayment plan requests $8 to $11 million of State general funds in 1969 so that provisions can be made during construction of the federal San Luis Drain for its future enlargement as a single, full-sized drainage canal for the entire San Joaquin Valley. Creation of the master district could then be deferred until after 1985 and its powers could be defined to reflect the economic conditions of that time. The repayment plan suggests that eventually some

combination of toll charges, taxes and government funds will provide the best means of recovering reimbursable drainage costs.

The Group stands ready to assist you in implementing the plan during 1969.

Sincerely yours,

Joseph B. Summers
Chairman

cc: Mr. Robert J. Pafford, Jr.
Regional Director, Region 2
U. S. Bureau of Reclamation
Department of Interior
2800 Cottage Way
Sacramento, California 95825

1. CONCLUSIONS

1. The most critical need for waste water disposal facilities exists in the northern part of the San Joaquin Valley. The disposal problems in other areas will become more severe in the future. Eventual need for disposal of waste water from most of the Valley is recognized. Waste water disposal must be provided to sustain the economy of the Valley and the entire State of California.

2. There is a three-fold problem that exists or can develop:

a. A high water table of poor quality.

b. A buildup of salts in the soil profile.

c. A salt balance in ground water bodies used for water supply.

3. It is exceedingly difficult to accurately forecast the quantity or quality of drainage effluent which will occur in the future. Some of the factors which make such estimates difficult are:

a. The quantity and quality of irrigation water applied within or upslope from the affected areas.

b. The dissimilar nature of the soils involved.

c. The extent irrigation return flows are reused.

4. Disposal of unusable waste water could be provided by one or a combination of the following:

a. Exportation from the Valley through one or more conduits.

b. Reclamation.

c. Irrigation of wildlife areas.

d. Evaporation.

5. For each particular area of the Valley and the conditions there at a given time, an economic analysis would generally favor one of the above methods, or a combination of methods, over other alternatives. The relative

economics of the methods can be expected to change from time to time in the future as actual needs become more definitely known and as the users develop more knowledge concerning alternatives 4-b, c and d. Future advances in technology of waste water reclamation may change techniques and/or reduce the cost of drainage disposal and conveyance.

6. The key to successful handling of the drainage problems of the San Joaquin Valley is to provide an immediate economically and financially feasible drainage disposal facility for use by those areas with presently critical problems and to permit a future determination of the most satisfactory long-range drainage disposal program for other areas.

7. Immediate need for service by a waste water disposal facility exists on the west side of the San Joaquin River for about 90 miles from near Mendota in Fresno County to near Tracy in San Joaquin County, and a satisfactory means for disposal must be provided for this area in the near future.

8. Over 80 percent of the presently irrigated and 76 percent of the future irrigated areas within the potential waste water disposal problem lands in Merced, Madera, and Fresno Counties are located west of the San Joaquin River. A drain canal from Gustine to Mendota is necessary to serve this area.

9. The construction of a single, joint-use, stage-constructed drain canal between Gustine and the Delta, instead of the federal San Luis Drain plus a separate adjacent state-constructed drain canal, may result in an estimated savings of $15 million.

10. Implementation of the single, federal-state, joint-use drain canal between Gustine and the Delta will require an appropriation of funds prior to July 1969.

11. The Bureau of Reclamation should have a responsibility to provide drainage disposal for all lands served water by Central Valley Project facilities. The State of California, Department of Water Resources, and the Bureau should have a responsibility to provide disposal service to other areas requiring service.

12. Federal and state waste water disposal facilities should be operated as joint-use facilities.

13. An entity with taxing powers, such as a drainage district, should be considered as a possible vehicle to repay reimbursable project costs.

Only a few members of the Group are in favor of the formation of a valley-wide district today. The majority would support the eventual formation of a drainage district. Some areas today do not want to be included in a drainage district until their needs are more definitely determined.

The Group recognizes the problem of excluding any lands on the valley floor from an entity which would support agricultural waste water disposal facilities but the problem has not been resolved. The exclusion of some agricultural land may make it difficult to include urban lands.

14. Drainage disposal problems are much akin to flood control problems. In this perspective, it is believed that the general public has a responsibility to help resolve the drainage disposal problem.

2. RECOMMENDATIONS

The Drainage Advisory Group recommends that:

1. As stated in Resolution 67-1 the State not acquire rights-of-way at this time for drainage disposal facilities south of Gustine.

2. As stated in Resolution 67-2, the U. S. Congress and California Legislature are urged to take action that would lead to the construction of a single, joint-use, full-sized, federal-state drainage facility between northern Merced County near Gustine and the Delta near Antioch Bridge. The wording of this resolution has been amended, changing the words "full-sized" to "stage-constructed".

3. The joint-use facilities described in Resolutions 67-2 and 68-2 should be constructed and the State and Federal Governments immediately undertake procedures necessary to implement, construct and operate the facilities in a manner similar to the San Luis Project joint-use facilities. The remainder of the proposed facilities should be expanded or constructed as needed.

4. As stated in Resolution 67-3, a joint study be conducted by the Department of Water Resources and Bureau of Reclamation for the development of an interim solution to the drainage problems in the area between Mendota and Oakley.

5. As stated in Resolution 68-1, the California State Legislature take action to provide funds that will permit the implementation of a joint-use, federal-state drainage disposal facility between Gustine and the Delta.

6. The State Legislature agree to provide financial support for this agricultural waste water disposal project as urged in Resolution 68-1 in a manner similar to the financial support provided for flood control projects, and appropriate or agree to pay about $8 million for the State's share of the initial financing of the joint-use facility between Gustine and the Delta to realize an estimated savings of $15 million. If a supplemental disposal facility is added to the San Luis Drain between Gustine and the Lemoore Naval Air Base either as an enlargement or adjacent canal, then the financial support necessary may increase to $11 million but a greater saving might be realized.

7. As stated in Resolution 68-2, the U. S. Congress and California Legislature are urged to take action that

would permit the joint use of federal and state disposal facilities when engineeringly and economically feasible and interim use of all units of the San Luis Drain by those users outside of the San Luis Unit service area when capacity is available.

8. The State Legislature request the State Department of Water Resources to negotiate with the Federal Government to implement joint-use facilities that will provide for present and future drainage disposal needs in the Valley.

9. Those agencies between Mendota and Tracy who are in need of disposal service proceed immediately to negotiate for permission for interim discharge of drain water into the San Luis Drain, the Kesterson Reservoir, and the first stage of a joint-use facility.

10. Wherever feasible, local entities should dispose of their agricultural waste water locally.

11. The Bureau of Reclamation should administratively establish a toll charge for use of drainage facilities for lands served by water purchased from the Delta-Mendota Canal.

12. As a means of project financing and repayment, consideration should be given to the formation of a drainage district.

13. All new water sales contracts in the Valley entered into by the State or Federal Governments contain provisions for drainage disposal charges.

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